Size (gallons).		Loading (kW.).	Recuperation Period (Hours).	Number of Baths in succession.	Pipe sizes.		Fixing Centres.		Outside dimensions of Cylinder.		Stand-by Losses per Week (kWh.).	Typical:—	
					Inlet.	Outlet.	Horizontal.	Vertical.	Diameter.	Length.		First Cost.	Quarterly Charge.
$1\frac{1}{2}$		0·5	1	—	$\frac{3}{8}''$	$\frac{1}{2}''$	9″	12″	10″	22″	4	£6	3/9
3		0·5	2	—	$\frac{3}{8}''$	$\frac{1}{2}''$	9″	12″	12″	27″	$5\frac{1}{2}$	£8 10*s.*	5/–
5	D	0·5	4	—	$\frac{1}{2}''$	$\frac{3}{4}''$	12″	16″	14″	30″	7	£10	5/6
12		1·0	$4\frac{1}{2}$	1	$\frac{3}{4}''$	1″	15″	24″	17″	38″	12	£13	7/3
15	C	1·5	4	1	$\frac{3}{4}''$	1″	18″	28″	18″	40″	14	£15	8/3
20		2·0	4	1–2	$\frac{3}{4}''$	1″	21″	32″	19″	45″	16	£19	10/6
30		2·5 [2]	$4\frac{1}{2}$	2–3	1″	1″	—		22″	50″	21	£26	14/–
40	P	3 [3]	5	3–4	1″	1″	—		24″	55″	24	£34	18/–
60		3 [4]	$7\frac{1}{2}$	4–5	$1\frac{1}{4}''$	$1\frac{1}{4}''$	—		27″	64″	29	£50	28/–

Sizes marked D are made in the displacement type; those marked P in the pressure type; and those marked C in the cistern type. First costs of cistern type are about £2 more than the figures given: the hire charges are also higher.

The sizes and loadings are those recommended by the Electrical Development Association. The loadings in square brackets are for night load heaters.

The dimensions, losses, and costs are approximate averages of a number of different makes.

ELECTRICAL WATER HEATING

WITH SPECIAL REFERENCE TO THE DOMESTIC STORAGE HEATER

BY

D. J. BOLTON, M.Sc., M.I.E.E.,
PHILIP C. HONEY
AND
N. S. RICHARDSON

SECOND IMPRESSION

LONDON
CHAPMAN & HALL, LTD.
11 HENRIETTA STREET, W.C.2
1935

Published by Chapman & Hall, Ltd., 11 Henrietta Street, London, W.C.2
Printed in Great Britain by The Whitefriars Press Ltd., London and Tonbridge
Bound by G. & J. Kitcat, Ltd., London

AUTHORS' PREFACE

To equip so small a book with three authors may seem a sin against proportion, but the subject, though not large, ranges over a big area and engages the services of a number of different experts. A perusal of the chapter headings will show a rough division into three parts, dealing respectively with the apparatus, the installation, and the supply. Each of these branches requires specialised treatment if electrical water heating is to attain the success for itself, and the service to the community, of which it is capable. Finally, and certainly not least, the consumer with a regard for his pocket must be served with what he wants at a price that he can afford.

In introducing this triple authorship it should be stated that Mr. Bolton has made a special study of the economics of electricity supply and domestic utilisation, and is the author of a number of papers thereon. Mr. Honey was for twelve years on the staff of the Croydon Electricity Undertaking. For most of this time he was directly responsible for their water heating business, and has now left them to take up similar work for the Electrical Development Association. Mr. Richardson is an installation engineer with a long and specialised experience of domestic water heating contracts. The harnessing of so diverse a team proved no small matter, and the necessary editing has been done by the first-named author.

In acknowledging the very great help obtained from all quarters, first place must be given to Mr. J. I. Bernard for his continual encouragement and advice. The following must also be thanked for permission to reproduce portions of articles or illustrations :—

The Editor of *Distribution*.
The Electrical Review.
The Electrical Times.
World Power.
Messrs. British Electrical Development Association.
Electric Fires, Ltd.
Benjamin Electric Ltd.
Geo. Bray & Co., Ltd.
Hotpoint Electric Appliances Co.

D. J. B.
P. C. H.
N. S. R.

CONTENTS

ELECTRICAL WATER HEATING

CHAPTER I

GENERAL CONSIDERATIONS: METHODS AND CHARACTERISTICS

Electricity—a New Principle. Hardly any domestic service is so appreciated as that of abundant hot water supply, and possibly none is more suited to electrical operation. Too long has water heating been thought of as a by-product—something for the kitchen range to do when it was doing nothing else. In optimistic moments perhaps the householder may have felt that he was getting his hot water for nothing: more often he paid very heavily in fuel and labour, and got a most unsatisfactory service in return. The time has come when hot water should be thought of as one of the major domestic requirements, and deserving of as much thought and planning as the structure and aspect of the house itself.

In recent years there has been a very considerable extension of electrical water heating, and both the householder and the supply authority are beginning to see in it the possibility of a common solution for their respective difficulties. There are, however, several problems to overcome, and pitfalls to be avoided, before it can achieve its full development. We are a conservative race and even when we take on a new idea we are loath to scrap an old one, but try rather to graft the one on to the other, a compromise that does less than justice to the new device. It must not be forgotten that the Englishman's house, like his trade, was founded on cheap coal, and from its cellar in the basement to its chimney stacks on the roof,

it is designed and planned for the open fire and the rapacious kitchen range. Even our domestic habits have become attuned to a weekly cycle of firing and cooking, so that it is the householder as well as the architect who is now called upon to change his mind. If only both these persons can be persuaded to "think electrically" and to shape their plans to suit the particular qualities of electrical heating methods, a steady and rapid development can be anticipated.

Until this educational process is completed it is important not to minimise the difficulties of the situation or to regard electrical water heating as a panacea which can be applied anywhere and everywhere. Equally mistaken is to go to the other extreme, and to condemn electrical water heating out of hand as definitely more expensive than other systems. Sometimes the objection is based on the old *a priori* argument which says that since the thermal efficiency of an electric supply system is normally less that of a fuel fired system, therefore the fuel costs must necessarily be more, quite apart from payment for the plant involved.

Such a line of argument contains several minor fallacies, *e.g.*, it compares fuel weights instead of fuel costs. The householder has to pay 40*s.* to 45*s.* a ton whilst the power station buys fuel only slightly inferior in calorific value for 16*s.* a ton. But it also contains one major fallacy because it is a comparison between quite different kinds of things. Electrical water heating is a *service:* it is a complete process in itself whereby the consumer in return for a quarterly payment obtains hot water at the desired places and times. Most systems which have been brought into a comparison have been only partial steps towards such a service. Besides paying fuel bills the householder has many other things to do. He must store fuel and order it whenever it runs short. He must light fires and clean up after them and he must plan his firing to suit the

anticipated demands, or *vice versâ*. His house is a power station in miniature, and fuel is only one of the expenses, albeit perhaps the only one directly assessable.

One has only to look at the coal, ash, and smoke-handling plant of a large modern station to see the enormous amount of dirty manual labour thus saved—labour which would otherwise be distributed over thousands of homes and soil many thousands of hands in the doing. The use of coal gas is one of the major steps on the householder's journey from fuel drudgery, and electrical heating is another and perhaps the final step in the same direction. In this respect it is, in fact, the logical conclusion of the movement so well initiated by the gas industry.

One stresses this point because it is vital to conceive of electrical water heating as a complete self-contained service on new lines, and not merely as an alternative way of applying heat to water. Just to take a fuel-fired or even a gas-fired installation and operate it electrically may easily lead to disaster with energy at its usual prices. Other times other manners, and a new system demands a new lay-out and a new scheme of operations. It must be remembered that electricity is a refined form of energy, much nearer to the final product than is the raw fuel from which it came. Electricity stands to coal very much as milk and meat stand to the grass or phosphates from which they were derived. To use it crudely and without discrimination is like using food-stuffs for manuring the fields.

Electricity, then, is a high-grade product and must be used wisely and carefully, not allowed to run to waste through leaky taps or endless piping, or in producing what is not required. It will then yield a high-grade result which can compare in cost and exceed in service any competing alternative. The first step is therefore to study the essential character of electrical heating so as to

find out where it excels and what are the weak spots in the armour. A scheme can then be devised which will fully utilise the one without unduly exposing the other. Before doing this it will be well to enumerate the chief alternative methods of water heating, with some notes on each.

Non-electrical Methods. The following is a short account of the chief alternative methods of water heating practised on an appreciable scale in this country. Needless to say, each of these systems has its particular uses and merits or it would not have survived to the extent that it has. Each also has certain faults and limitations, some of which are indicated below.

Coal-heated "Copper." This is probably the most expensive way of all if labour costs are taken into account, since the fire has to be specially lit for each quantity of water used. As a consequence it is generally put in service only once or twice a week, and all baths and clothes washings are arranged to fit in with this. It is not suitable for sink and basin supply, and is essentially intermittent rather than continuous in its operation.

Coal-fired Range or Grate (having boiler at back or side). This is a by-product system, since the water is heated in addition to cooking and/or room heating. Like all by-product schemes, its success depends largely on careful time co-ordination. If the washing habits of the household are carefully fitted into the cooking and firing schedule all may be well, but woe betide anyone who comes home late at night and demands a hot bath without notice. The hot water system is rarely lagged and therefore the hot water must be used within a few hours of the corresponding coal consumption if heavy losses are to be avoided. On the other hand, the storage system may serve subsidiary purposes in the shape of clothes airing, etc. Usually the fire is lighted afresh each day,

and when bituminous coal is burnt, the flue passages require frequent brushing if efficient results are to be maintained. Naturally the labour involved is considerable, but here again this may serve as a part-time occupation for energies that would otherwise be wasted.

Independent Boiler (usually coke-fired). This gives good results when properly fired and attended to. Generally the fire is kept burning continuously and labour charges are considerably less. It follows, however, that for efficient results it is essential for there to be a fairly considerable and regular consumption of hot water, since an appreciable amount of fuel is required merely to keep the fire alight even when no water is used at all. As in the last case, lagging is rarely employed, so that there must not be a big time lag between fuel consumption and water utilisation.

In general, the larger and more continuous the load, the more satisfactory the results. Spasmodic use will prove costly, and although the attention required is not great, it must be careful and intelligent if good results are to be obtained. The same system can be used for heating radiators in the hall or elsewhere, and it also, incidentally, warms the kitchen or other room in which the fire operates. This latter is an advantage during a considerable part of the year but a disadvantage in summer.

The last-named disadvantage can be overcome, and the fuel cost reduced by only lighting occasionally during the summer, *e.g.*, once or twice a week for clothes and bath water. This, however, gives nothing for basin and sink use at any other times, and cannot in any way be regarded as an adequate hot water service. A far better arrangement is obtained by combining an independent boiler with an immersion heater electrical installation put into operation throughout the summer months.

Gas heating of an independent boiler system is another plan that has been tried. Since the heat must be applied

in the boiler itself and not (as with an immersion heater) in the tank, this means that the full radiation losses are experienced in the boiler and in the flow and return pipes. Such an arrangement is therefore necessarily less efficient, and is rarely employed except for obtaining intermittent or short period supplies.

One noticeable feature, common to all the systems so far described, is that there is no essential connection whatsoever between fuel consumption and water utilisation. It is true that the firing is done by someone in the house, who will presumably adjust it, to some extent, to the anticipated needs of the next few hours. The point is that there is nothing to *ensure* this being so, or to prevent combustion proceeding at a high rate when little water is required. Such systems are very much at the mercy of extravagant or careless staff, and even when operated with care there are limits to what can be done without letting the fire out. The minimum setting of the air supply necessary to maintain combustion through the night, etc., varies with the weather and flue conditions, and it may be found that even if no water is used at all, the fuel consumption is not less than about half that taken at the full rate of burning.

The nearest approach to automatic control in domestic systems is a thermostatic device which can be fitted in the return pipe and which will open or close the air inlet and so regulate the rate of combustion. This may be useful as a check on excessive night burning, but the time lag is so great and the combustion limits are so considerable that it is impossible to obtain any fine or immediate regulation of coal-firing by this means. Oil-firing, which is sometimes used in offices and institutions, is so rare in private houses that it is not discussed here.

Instantaneous Gas Heater or "Geyser." This is a cylindrical (occasionally rectangular) water heater, not usually lagged. The water passes through a series of

troughs or a coil of piping, whilst the gas burns in jets at the bottom and the hot vapours pass round the water container. It can either be of the displacement type with a single spout outlet over bath or basin, or else of the semi-pressure type feeding several points. In the latter case the geyser has a pilot jet always alight and is supplied with water at a certain head. The outlet is then connected to the hot-water tap system. When any tap is opened and water flows from the geyser this automatically causes the gas to go on fully so that after a few seconds hot water is obtained. This latter type can also be made to take the full mains pressure, although such an arrangement is frequently forbidden by the water undertaking. In all cases of multi-point geysers, safety depends on the correct operation of an automatic spring-controlled valve. It is therefore not surprising that maintenance is a considerable item in the cost of this system.

Since the above apparatus is one of the principal competitors of the electric water heater, and is frequently brought into comparison with it, a few facts regarding this comparison should be set out. Gas is measured in cubic feet and paid for in therms, one therm being 100,000 B.Th.Us. But of this potential heat energy only a certain proportion is imparted to the water. In the first place combustion is never perfect, particularly when the jets have become partially sooted up. Some of the chemical energy of the gas therefore never turns into heat at all. In the second place, of the heat produced a considerable portion goes up the flue, as may easily be discovered by feeling the heat of the exhaust gases even a considerable distance away from the actual geyser. This proportion also gets worse with time, since scale, etc., will line the walls of the water chamber and so reduce the amount of heat passing through to the water. Finally, of the heat imparted to the water some of it is wasted in producing steam. To raise a given quantity of water

through the normal bath temperature rise of 60° F. requires a certain quantity of heat. To evaporate the same quantity of water without raising its temperature at all requires sixteen times as much heat. Since the steam is a useless product the heat thus spent is entirely wasted.

The above effects are set out here because so often the cost and heat content of the kilowatt-hour is compared unfavourably with that of the therm. In the electrical case every particle of the heat capacity of the kWh. is necessarily developed in actual heat. Anything not so consumed would not be registered on the meter. Moreover, the element is surrounded by water so that all the heat developed is directly imparted to it. Any losses which occur do so subsequently and from the water itself. Furthermore, these facts are independent of the condition or age of the heater. They are a corollary of the law of conservation of energy, since in this case the energy has nowhere else to go except in heating the water.

Apart from questions of thermal efficiency the chief defect experienced with the gas geyser is its slowness of operation. The gas pressure in most mains fluctuates considerably at different times of the day and year, and naturally it tends to be least when it is most wanted, *i.e.*, when everybody is using it. In winter the temperature in the water mains is very much lower than in summer, and at the same time hotter baths are generally required. As a result the bath may take a considerable time to fill. In the meantime the whole body of water is cooling, and delay is frequently complained of.

It is easy to form a rough idea of what this delay is likely to be. One of the most popular sizes of gas geyser is claimed to give $2\frac{1}{2}$ gallons per minute with a 40° F. rise. To obtain a 30-gallon bath at 104° F. will require a running-in temperature some 10° F. higher owing to the time taken to run in. This means 114° F., which is 60° F. above the annual mean temperature in the water mains.

Now $2\frac{1}{2}$ gallons a minute for 40° F. rise means $1\frac{2}{3}$ gallons a minute for 60° F. rise—*i.e.*, approximately 20 minutes for a 30-gallon bath. Moreover, this is the maker's rating for the geyser as newly made, and when well served with gas pressure. What is likely to be its performance after some years of use or during peak loads on the gas mains? Again, the mid-winter temperature in the water mains is such that the heat to be imparted to the water is 22 per cent. higher than the value figured above, and this means a correspondingly longer time to run in, and still greater cooling.

The above characteristic is the inevitable result of applying the heat as the water is flowing in, since a large amount of energy has to be transferred in a comparatively short time. The steam production, and to some extent the scaling, is also the result of having to impart a large quantity of heat in the few minutes of use. This is in marked contrast to the storage heater where the heat is imparted relatively slowly, although the whole boilerful can be used straight off if required.

Another disadvantage of this type of geyser is that a flue is required as well as a large gas supply pipe. This adds to the installation costs, and too often results in an unsightly cowl or flue vent projecting from wall or window top. Moreover, the combustion requires and absorbs a large amount of fresh air which must find its way, by windows or under doors, into the room when the geyser is burning. It is for this reason that the authorities always direct that a door or window should be left open whenever a geyser is in operation.

Gas Storage Heater. This was designed to reap some of the popularity sown by the electric storage heater. Its advantage over the instantaneous geyser is that it is a more uniform load on the gas mains and less likely to produce pressure fluctuations, and less affected by them. No loss of time occurs in drawing off the bath water, but on the other hand there is a limit to the number that can

be drawn off in succession, this depending entirely on the capacity of the heater. Since the rate of gas consumption is smaller, a flue is frequently not fitted and is commonly stated to be unnecessary. This claim, however, requires a little further investigation, since gas consumption on a scale sufficient to provide domestic hot water clearly cannot take place without the using up of a considerable quantity of fresh air and the discharging into the atmosphere of a corresponding amount of vitiated air.

Taking a moderate water consumption for a small family, and assuming a normal overall efficiency, this will mean a gas consumption of 5 cub. ft. per hour even if spread uniformly throughout the twenty-four hours (an obvious impossibility for a thermostatically-controlled heater). Now a figure which has been suggested for the vitiation of air by the products of gas consumption is to regard each cubic foot of coal gas burnt per hour as equivalent to one person.[1] Even if limited to 10 cub. ft. per hour, the flue-less gas heater would still be equivalent to 10 adult persons whenever it is in operation. Such a complication of the ventilation problem in a modern small house or flat is hardly to be welcomed.

Moreover, the above is on the assumption that the gas is all perfectly consumed—a somewhat optimistic assumption after the heater has been some time in use, possibly without frequent and skilled attention. Any imperfection in the burners or air supply may then result in poisonous as well as spent gases being discharged into the room. It is unfortunate that in a matter so vital to general health and indoor comfort there is no authoritative medical opinion that can be quoted, whilst individual verdicts are

[1] "In buildings lighted by gas or oil, the calculations for the supply of fresh air and the extraction of foul air must include an allowance for the vitiation of air by the products of combustion. The rate at which this takes place may be roughly estimated in the case of gas by treating each cubic foot of gas burned per hour as equal to one person."—"Encyclopædia Britannica," Vol. 23, 14th Edition, pp. 68, 69.

inevitably suspect where such powerful vested interests are at stake. A purely personal experience with kindred apparatus, namely, portable flueless fires for room heating, is that unless large additional ventilation is provided a headache invariably supervenes.

In addition to atmosphere pollution there is also the condensation of water from the exhaust gases. The combustion of 10 cub. ft. of gas results in a quarter of a pint of water which must be got rid of every hour. With insufficient ventilation this will condense on the walls, etc., causing continual trouble.

Characteristics of Electrical Method. It will be convenient for a moment to refer again to the various methods of water heating outlined above and to insert the electrical method at the end of the list. When this is done they will be arranged roughly in their historical order, which is also the order of the amount of labour involved in their operation. Starting with the range or open fire burning crude coal, continuing with the independent boiler (burning coke or oil), then to the various gas-heaters, and coming finally to the electric water-heater, it will be noticed that the heating agent is becoming steadily more refined as the list is gone through.

Certain things follow from this fact. One is that the cost of the energy (potential or actual) in the heating agent goes steadily up. Oil is about twice as expensive as coal or coke for given B.Th.U. content, gas seven, electricity ten to fifteen times. A second thing which follows is that, since more and more labour is expended on the heating agent before it enters the house, less and less remains to be done by the householder. Obviously, the labour required in the consumption of gas, and more markedly still of electricity, is far less than that required with coal or coke, or even with oil.

The above sequence may be regarded as a particular example of the general movement towards more and more

specialisation and division of labour. We no longer make our own boots and suits, we are beginning to buy our potatoes ready peeled, and now we are going to get our coal handling done for us. Moreover, as amenities increase and become wider spread, as the general public comes to enjoy the wealth that the engineers have already made possible, this tendency will necessarily go still further. Labour for the the dirtier and heavier forms of housework will become increasingly difficult to hire, and everything possible will be done outside and by machinery, rather than inside and by hand.

Combustion and Utilisation. The electrical method, then, is quite in line with the modern tendency to depute all specialised responsibilities to the particular technician concerned, and to buy a "service." But it is something more. Besides being the end point of a sequence it is also unique in one important respect, namely, in the complete separation of fuel combustion from heat utilisation. In all other hot water systems the householder is responsible for the actual combustion; in the electrical one he is not. Now combustion is a tricky business and essentially one for the professional expert. To be efficient it should be continuous, on a large scale, preferably away from residential areas, and with every possible aid in labour saving and fuel technology. The householder's interest is in utilisation: he does not want to be bothered with the production end, and the less he sees of it the better pleased will he be.

Certain consequences follow directly from this separation of fuel combustion and heat utilisation. In the first place there is the saving of labour and dirt, already touched upon, and here carried to its ultimate limit. Then there is the complete flexibility and ease of control. The householder consumes exactly how and when he pleases, while, thanks to the diversity of users and of uses, fuel combustion goes on continuously.

Since there is no combustion, no chimneys or flues are required, nor can there possibly be any fumes or smoke, nor vitiation of the atmosphere, even in the event of a fault developing in the apparatus or the installation. No combination of wind or weather can make the slightest difference to its operation, and this, like the previous claim, is one that can very rarely be made for any other system *as actually installed*. For the same reason, room decorations are not soiled and an appreciable saving often results on this score alone. Again, the heating element can be split up as desired and the heat developed exactly where it is wanted, without regard to ventilation needs, and in large or small amounts with equal efficiency.

Finally there is the possibility of completely automatic operation with the simplest of means, giving a steady supply temperature at all times, with consumption only to suit needs.

Smoke Abatement. There is no need to do more than mention the civic aspect of the use of electricity instead of coal as a heating agent. Just how much of the disease, dirt and lack of active sunlight of our large towns is due to the consumption (always imperfect) of small quantities of raw fuel from house to house cannot be said, but certainly it is very considerable. As late as 1922, 20 per cent. of our total coal consumption was burnt in domestic grates, and this was six times as much as that consumed by authorised electricity undertakings for all purposes—lighting, heating and power. The cost of these indirect effects of domestic coal consumption, including the extra cleaning and health services, fogs precipitated, etc., would be sufficient to subsidise the domestic consumption of fuel alternatives and effect a prevention of what we now attempt merely to alleviate. Even the traffic problem would be sensibly diminished if there were no coal carts in the streets, and if all coal trucks went directly to a few large stations instead of cluttering up the termini of busy capitals.

Safety. There are two ways in which the safety of a system can be evaluated. One way is to consider the intrinsic properties of the apparatus employed and to assess the likelihood and extent of possible accidents. The other way is to examine records of actual practice, the statistics of insurance undertakings and of firms who do the hire and maintenance work. Both these methods of approach show electrical water heating to have a very high factor of reliability and freedom from accidents or danger.

Consider, first, the intrinsic merits. Electricity supply is guarded by fuses and other overload protection at far more points than is any other form of supply. It is more easily cut off, and in the event of overload it cuts itself off. Electricity cannot slowly accumulate at one point so that there is very little possibility of an explosion even if a fault develops. In the storage heater, the heat is applied slowly and over long periods so that there are no sudden temperature changes, and no part of the apparatus is heavily stressed. Finally, water heaters are necessarily earthed by reason of their pipe connections, quite apart from any other earthing provision that may be made, so that a shock is well-nigh impossible.

These theoretical considerations are fully borne out by the results of practical experience. The percentage that has to be put aside for repairs is lower than on most competing apparatus, and the records of accidents or damage to life or property are very much lower.

Service. It is difficult to make a general comparison between electrical and other methods of water heating on the grounds of service to the user because there are so many other methods, each with its own particular characteristics. All that can be done is to compare two systems which claim to give identical service, and see how these claims are substantiated. When this is done it will usually be found that in comparing the electrical

with the non-electrical method, the former gives just a little better service over the same field.

In the case of a multi-point supply the electric heater gives both a quicker and a hotter service. This is because the distance to the storage vessel is normally less with an electric than with an independent boiler installation, and a higher storage temperature is feasible in a self-contained heater than in a triple arrangement of boiler, tank and circulating pipes. There is a similar advantage over a multi-point geyser supply, since in the electric case the water is already hot and is merely waiting to flow along the pipe, whereas the automatic geyser only commences to heat the water when the tap is turned.

The same result can be seen in comparing two other apparently identical services, namely that given by a displacement heater mounted between basin and bath and that given by a simple gas geyser. Nine times out of ten when a little basin water is required it is just too much trouble to light the gas, and cold water is used instead. Moreover, the frequent lighting up for small quantities of water is extremely inefficient both in gas and in time. But with an electric heater the hot water is there already, and the exact quantity required can be instantly obtained. The proof of these facts is that when an electrical installation takes the place of some other, even one giving a reputedly identical service, the hot water consumption usually shows a distinct increase.

Two other features of electrical operation have an important bearing on the question of service. One feature which is found in almost all branches of electrical utilisation is that the efficiency is very little affected by the size. While most processes require to be done on a large scale in order to be effective, the use of electricity can be subdivided almost indefinitely with very little loss in efficiency. A second feature is that this efficiency

is maintained over a period, and without attention, to a degree that cannot be approached by any other system. As a result it is now possible for the smallest household and the most unattended system to have a hot water service such as was at one time only possible from an expensive installation and with the most unremitting attention.

Running Costs. No attempt at a detailed economic comparison between the different methods of water heating will be attempted here. The book aims throughout at being descriptive and informative rather than didactic and argumentative. It is the easiest matter in the world to take a brand new water-heating appliance, operate it under perfect conditions and then, after a few lightening calculations, to announce—"so many baths for a penny." The data is indisputable, and the calculations are beyond reproach: all that can be questioned is the relevance of the whole affair.

Whilst this is the easiest matter in the world, one of the hardest is to obtain results under normal working conditions with apparatus in its average state, and to get a ratio between water actually obtained at the tap and the costs of the fuel and labour involved. The most nearly comparable systems as regards labour and service are, of course, gas and electricity, and in this case a rough parallel can be established. It will be assumed that a displacement type electric storage heater is being compared with either an instantaneous geyser or a storage gas heater supplying one point in each case. Alternatively the comparison can be made between a pressure type electric installation supplying several points and a multi-point gas installation either instantaneous or storage. Under these circumstances it may be taken that running costs with electricity at $\frac{1}{2}d.$ per kWh. will be roughly equivalent to those with gas at $8d.$ per therm. Electricity at $\frac{3}{4}d.$ will be similarly equivalent to gas at

1*s*., whilst electricity at $\frac{1}{3}d$. will be equivalent to gas at 6*d*. or 7*d*.

The figures on which the above estimates are based represent in every case the average efficiency, over a period, of domestic apparatus in the normal state of maintenance, and not that of new plant under test conditions. In the third case mentioned (electricity at $\frac{1}{3}d$.) a lower efficiency has been taken for the electrical installation than in the other cases. This is intended to apply to night storage cisterns or immersion heater installations, since electricity at this price is usually only supplied for night loads or else during the summer months.

In the case of fuel-fired systems the fallacy of comparing the fuel costs of the one with the electricity costs of the other has already been touched upon. It is rather like comparing the cost of food with the price of a meal at a restaurant. Apart from this it may be said that independent boiler systems are usually cheaper in fuel costs alone when a large and regular hot water consumption is being taken. They become less efficient the more spasmodic the load, and in the extreme case the standby loss (when no water is used at all) is far higher than that of either gas or electricity. The various combined heating and cooking systems are almost impossible to compare in costs, but the extra labour involved is rapidly putting them out of court. In all solid fuel systems there is also the necessity for fuel storage and its periodical ordering. Particularly in flats, and in subdivided houses, storage and carrying-up is often a very considerable problem.

There are also many incidental wastages both of time and money which may be saved, particularly in the kitchen. It is a common practice to keep a kettle of water on and off the boil for hours a day merely to provide comparatively small quantities of cooking and washing-up water when needed. Apart from the low thermal

efficiency involved in the external heating of a kettle, the quantity is often wrongly estimated and much of it is wasted. With a small electric water heater mounted close to the sink the correct amount is drawn off exactly when and as it is needed, and the daily overall efficiency may work out at 90 per cent. instead of about 9 per cent.

In general it may be reckoned that in a district which is well served with alternative sources in the way of gas, coke and coal, electrical water heating is likely to be competitive in running costs (all items being allowed for) wherever there is a heating rate (or secondary rate of a two-part tariff) of $\frac{3}{4}d.$ to $\frac{1}{2}d.$ per kWh. Reasons are given in Chapter VIII for believing that such a rate is a perfectly sound figure for the supply undertaking to offer, and in point of fact these rates are now fairly general in urban and industrialised areas. In country districts where the distribution costs are higher and the alternative services less good, a price of 1*d.* to $\frac{3}{4}d.$ per kWh. should be equally competitive. On the other hand, restricted hour or off-peak supplies (necessitating larger equipment or giving a less complete service) will generally need a price range of $\frac{1}{2}d.$ to $\frac{1}{3}d.$ per kWh. to make them equally attractive.

Further than this the authors are not prepared to go. As stated above, they are anxious to assist those already interested in the electrical water heating process rather than to provide materials for a debate. They are quite satisfied that, provided it is properly understood by the installation engineer and adequately backed by the supply authority, electricity will give a hot water service competing in costs, and more than competing in convenience and facility, with any alternative system. Electrical water heating has grown from very small things in a comparatively short time. Such growth can only be the result either of extensive advertising or intensive merits. The former it certainly has not had—in proportion to its novelty and the activity of its competitors

the amount of publicity devoted to it has been relatively small. Its growth has therefore been purely on merits, and these merits promise a steady continuation of this growth. Proper understanding of the electrical method is the keynote, and to assist such understanding is the aim of the present book.

Summary and Conclusion. The two essential characteristics of electrical water heating can be summarised as follows :—

(i.) All the potential energy paid for by the consumer is actually developed in the heating element, irrespective of age or condition.

(ii.) Exact control and localisation of the heat supply ensures that the consumption shall precisely match the needs.

Provided these features are fully exploited there should be no serious difficulty in any comparison of operating costs. All the other many-fold advantages of electricity will then be so much overweight—the immediate response at the tap, the cleanliness, the absence of oxygen consumption or fume production, and the freedom from any need for worry on the part of the householder.

The chapter may usefully be concluded by re-stating what was said at the commencement. Electrical water heating is a complete system or service in itself, and must be judged and planned accordingly—not strangled at birth by the chop logic of heat equivalents nor given a lingering death grafted on to an inefficient installation. One does not burn petrol in a diesel engine, and our problem is to study the new fuel and to devise the appropriate machinery.

This book is intended as a small contribution to this proper study of electrical water heating. Very little data has so far been available, although there is no direction in which study would be better repaid. Just because it is

a finer product, electricity and its efficient application is in greater need of scientific planning. Once installed it is well-nigh "fool proof," but the right start is everything, and this both needs and deserves expert handling, based on the finest advice obtainable.

CHAPTER II

HEATER CONSTRUCTION

Instantaneous Heater or "Electric Geyser." In this type the heater switch is turned on as the cold water inlet tap is opened. Water flows past the heater element and becomes warmed immediately preceding its use. The apparatus is therefore the electrical equivalent of the gas geyser to which reference has already been made.

Fig. 1 shows an electrical geyser of this type, designed for sink and basin use. The rating is 4 kW., and the delivery rate is approximately 3 pints of hot water a minute. The electric circuit is entirely insulated and the switch and water handle are interlocked to prevent running dry. Similar heaters are made with higher ratings for bath use.

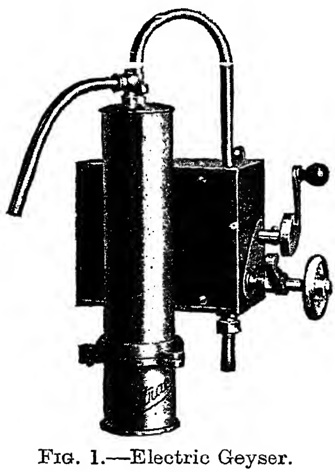


FIG. 1.—Electric Geyser.

Instantaneous heaters utilising bare immersed elements have made their appearance from time to time, but their general adoption seems doubtful (apart from other circumstances) in view of Paragraph No. 1345 of the Institute of Electrical Engineers' Regulations for the Electrical Equipment of Buildings (10th Edition, 1934), which reads :—

> " Water-heaters and boilers, other than electrode water-heaters and electrode boilers, shall be of such

a type that the water is not in direct electrical contact with that portion of the heating element which is live."

Moreover, in the case of electrode water-heaters and boilers, these have to be provided with various safety devices, earth leakage trips, etc., which obviously rule out the use of such apparatus for domestic use.

The Electric Supply Regulations made by the Electricity Commissioners contain the following :—

> "*Para.* 25. In the case of electric (lines and) apparatus situated on the premises of a consumer and belonging to the Undertakers or under their control the Undertakers shall be responsible for such electric (lines and) apparatus being installed and maintained in a safe condition and suitable for their respective purposes and being so fixed and protected as to prevent the *possibility of leakage* to any adjacent metal.
>
> "Provided that any such electric (lines and) apparatus which comply with the provisions of the Regulations for the Electrical Equipment of Buildings issued by the Institute of Electrical Engineers and for the time being current shall be deemed to fulfil the requirements of this Regulation in respect of installation and maintenance."

Paragraph 26 also specifies the maximum leakage allowable, which amounts to 1/10,000th of the maximum current to be supplied (presumably of the total connected load on that particular meter).

The manufacturers of bare element heaters claim a very high efficiency for their apparatus owing to the direct contact obtained between the water and the heating element. There is, however, a possibility of the user getting a shock under certain circumstances when the earthing of the heater is not carried out properly, which has made supply authorities generally unwilling to con-

nect them, especially when the heater or geyser is of the portable type.

Advantages and Disadvantages of Instantaneous Type. The advantages of this type of electric water heater are that it occupies very little space, and that even if left unused for a long period there are no stand-by losses to pay for. In the matter of compactness it is far ahead of any alternative, electric or otherwise.

The disadvantages are, in general, more serious, and chiefly concern themselves with the question of rating or size of heating element. It was mentioned in connection with gas geysers that, in order to get really hot water in winter, it is often necessary to reduce the water flow to such an extent that a bath takes half an hour or more to draw, particularly when the gas pressure is low.

In the case of electrical geysers or instantaneous water heaters the fluctuations in supply pressure are far less than with gas supply, but the ratings are usually so much smaller in the first place that the slowness is even more noticeable. The following table shows the outputs claimed by the makers for two common sizes of gas geyser and the equivalent kilowatt rating, *i.e.*, the power required at unity efficiency to give these stated outputs. This is a purely superficial comparison and not based on test results. It is, however, sufficient to give a fair idea of the difficulty of designing an electrical geyser.

	Stated Output for 40° F. rise.	Electrical Equivalent. kW.
Normal domestic geyser	2 galls. per min.	14
Large ,, ,,	[illegible]	

Another way of putting it would be to say that since about 4 kWh. are required for one hot bath, to obtain this in twenty minutes requires a 12-kW. rating. A

second defect is that owing to the large heat transfer in a small time the immediate efficiency is lower. Some degree of steam is produced and scaling is more pronounced. The loss on this score is, however, largely balanced by the absence of any stand-by losses.

The obvious disadvantage of a high loading from the electrical standpoint is that it means a heavy power demand lasting for a short period—*i.e.*, a poor load factor. If there are two geysers connected to the mains and supplying the same amount of hot water, one an instantaneous type with a 10-kW. element and the other a storage heater with a 2-kW. element, then the latter will be energised (on the average) for five times as long as the former and will have five times as good a load factor. Any supply engineer will greatly prefer the higher load factor apparatus, and in fact on an ordinary two-part power tariff the instantaneous type mentioned above would pay five times as great a fixed charge. This, however, is not usually done with domestic apparatus and, moreover, would not be fair, since the instantaneous heater (as a direct result of its short energised periods) has a much better diversity. That is to say, there is less chance of the use period clashing with the use periods of other apparatus and so piling up the demand. The upshot is that such a load is more expensive to supply but not in the full ratio of the increased loading.

Another important consideration is that of regulation or voltage drop. The short period of use and the consequent diversity effect will prevent the instantaneous heater load from producing noticeable effects at the sub-station or at any point further back in the system. But the local effect is likely to be very bad. The sudden coming on and off of a heavy load in a house will affect the lights in that house and probably adjoining houses, unless all the wire sections are very ample. Voltage

balance between phases or between the halves of a three-wire D.C. system (always a difficult problem) will be made more difficult.

In selecting a suitable rating for an instantaneous heater it is therefore necessary to compromise and to take a mean between the high values necessary to give a good water flow and the much lower values preferred by the supply undertaking. Values of 4–6 kW. are sufficient for basin and sink use only, but 8–12 kW. are necessary if a bath supply is required. Some supply authorities restrict the use of such heaters on their mains by limiting the rating to a maximum of 3 kW. or by compelling any larger loading to be switched on only in 10 ampere steps. Another limiting feature is the scaling which occurs in hard water districts.

Instantaneous heaters, because of the very small space that they occupy and the absence of standby losses, undoubtedly have a field of application, but it is a very narrow one, and generally only where small quantities of water are required. One example is when hot water is needed at short notice but on very infrequent occasions, as in ambulance rooms. In such a case it would be uneconomical to keep a storage heater connected possibly for weeks at a time without any call being made on it. At the other extreme there would appear to be a field for the instantaneous heater when the hot water requirements are regular and almost continuous.

A heater which is intermediate between the above instantaneous type and the storage type described below is the unlagged heater (p. 64 and Fig. 17). For bath use this has a loading of 3 or 4 kW. and is switched on about an hour before the bath is required. Where space and first cost are vital considerations such a heater may form an acceptable substitute for a full storage installation, whilst its loading is preferable to that of an instantaneous heater.

Storage Heaters. The only alternative to a powerful element, heating the water as it is flowing out, is the employment of a low rated element connected over longer periods. This necessitates the storing of a sufficient quantity of water, and protecting it from heat losses. The storage heater is therefore the logical expression of

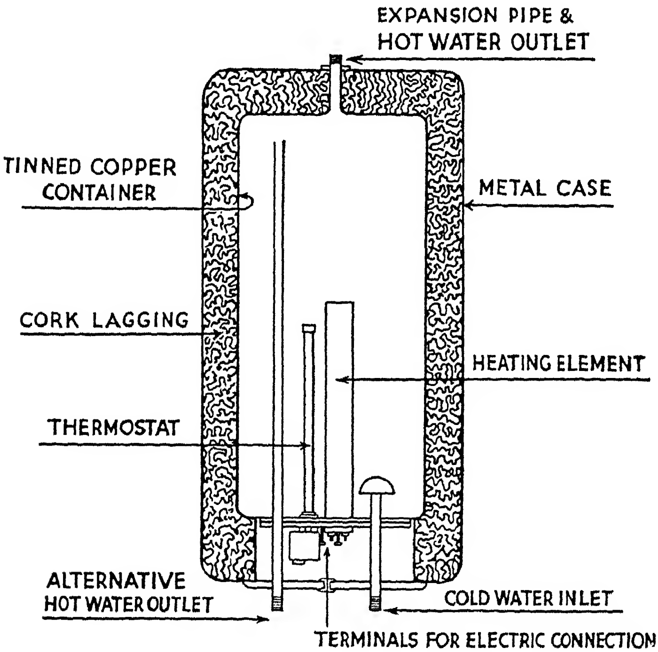


FIG. 2.—Principle of Storage Heater.

the supply aspect of electrical water heating. In this apparatus, electrical water heating appears to have developed a style of its own and an appropriate embodiment. The undertaking finds in it an acceptable daily and yearly load factor. The domestic user finds its sole demerit (compared with the previous type) to be the space it occupies, and in return for this he obtains an immediate

and rapid flow of really hot water at any time without notice.

The essential features of a storage heater are shown in Fig. 2. The water fills, or nearly fills, the inner container, usually made of tinned copper and almost always in the form of a vertical cylinder. Surrounding this is a thick lagging of some heat-insulating material. The heating element, shown in the figure as a vertical tube or bar, is sometimes known as an immersion heater[1] because it is entirely surrounded by the water which is to be heated. It is usually vertical, and in this case it runs up the middle of the water container and extends from the bottom to about half-way up, or rather more. Control is very generally automatic, and a thermostat is shown close to the immersion heater, and, of course, equally surrounded with water. All the above apparatus, together with the necessary inlet and other pipes, is usually mounted on an "apparatus plate" which, with a watertight joint, forms the base of the water container. The switchgear and terminals fix to the lower side of this plate, and these in turn are protected by a loose-fitting cover.

The operation of the storage heater is as follows. The thermostat is set so that at a certain maximum temperature (say 180° F.) it cuts out and breaks the circuit, whilst at a certain lower temperature, say 170° F., it cuts in again and completes the circuit. The cutting-out point is known as the thermostat setting, and the difference between the two points is known as the thermostat differential. The cylinder is always full of water, and the thermostat takes up the mean temperature of the water surrounding it. When the heater is first connected

[1] More usually the name "immersion heater" is applied only to such heater elements when they are supplied as separate units and screwed into existing tanks, thus converting a non-electric into an electric system. With this use of the term (which will be followed throughout the present work), an "immersion heater" installation is one in which a complete or self-contained "water heater" or "boiler" is not employed.

into circuit the water will be cold and the circuit will therefore not be broken by the thermostat switch. After a time the water will have become raised to the temperature of the thermostat setting and the switch will break the circuit. Cooling will then set in, either slowly due to heat losses, or much more quickly if hot water is drawn off and cold take its place. Sooner or later, the water will reach the lower temperature point, and the thermostat will then cut in again and heating will recommence.

In the matter of piping, etc., there are three forms of the storage heater in general use. These are fully described in the next chapter dealing with types and uses, but it will be well to enumerate them at this point. In the *non-pressure* or *displacement* type the tap is placed on the cold pipe leading into the heater. The outgoing hot pipe carries no tap—it is an open spout, so that the heater cannot possibly have any pressure in it, and only one hot point can be supplied. The water does not quite fill the cylinder, and the arrangement at the top is as shown in the figure. When the tap is turned on, cold water flows in at the bottom and this raises the level so that hot water overflows at the top. In the *pressure* type (sometimes called semi-pressure) the taps are on the outgoing hot pipes, as in the ordinary hot water system, and any number of points can be supplied. The cylinder must therefore work at sufficient head of pressure to be able to send water to the highest point served. The cylinder is in this case completely full of water, and as hot water is drawn off, cold water enters at the pressure just mentioned. The pressure in the ordinary water mains is often higher than is wanted for this purpose, and for this and other reasons a supply from a ball-valve cistern at the top of the house is preferable. When this is not available a *cistern* type heater can be used. This embodies a complete ball-valve cistern on top of the heater tank. The water

in the heater tank will then not be under pressure so that the heater must be mounted above all the taps.

Heat Losses.[1] The merits of service are inevitably qualified by the disabilities of expense. When one has pointed out the convenience of having a quantity of very hot water always in readiness, the question naturally arises as to the cost of having it so. Supposing it is there for a week and never drawn upon, what will the charge amount to? This question is discussed in the following paragraphs.

Heat passes from a hot body to its surroundings by three different methods—conduction, convection and radiation. Conduction occurs through any continuous material but chiefly through metals. Convection occurs through the movement of the medium, which must therefore be a fluid (*i.e.*, liquid or gas). Radiation occurs across the medium, which must therefore be transparent to these rays (*i.e.*, in general a gas or empty space). Conduction will be confined to the pipes and supporting brackets, and even this small quantity mostly serves to warm the incoming or outgoing water. The conduction losses are therefore usually negligible, but the other two kinds must be considered in further detail.

Convection is dependent on the temperature difference between the hot and cold surfaces, but not on their absolute temperatures. It is proportional to surface area and it varies somewhat with shape and position, but it is independent of the character of the surface (*i.e.*, colour or smoothness). Its value is $K_c\theta^{5/4}$ B.Th.Us. per hour per square foot of hot surface, where θ is the temperature difference in °F., and the constant K_c has the following values :—

0·4 for a horizontal surface facing upward.
0·2 ,, ,, ,, ,, downward.
0·3 for a tall vertical surface.

[1] Data from "Food Investigation No. 9," Department of Scientific and Industrial Research, H.M. Stationery Office.

Thus a vertical surface is a mean between the two horizontal ones so that a horizontal cylinder or large pipe is equivalent to a tall vertical wall of the same surface area. For short vertical surfaces and for small horizontal pipes the loss is more in proportion. Thus the value of 0·3 will become 0·4 for a wall 8 in. high or for a pipe 1 in. external diameter ($\frac{3}{4}$ in. bore).

Radiation is proportional to the fourth power of the absolute temperature and is greatly dependent on the character of the surface. It is independent of the movement or nature of the medium, provided this is transparent, and it takes place equally in all directions, so that it is proportional to the radiating surface area whatever the shape or size. For a dull black body (to which rough iron will approximate) its value is $K_R(T_1^4 - T_0^4)$ B.Th.Us. per hour per square foot of hot surface, where T_1 and T_0 are the hot and cold temperatures in ° F. absolute (*i.e.*, ° F. + 460) and K_R is $1{\cdot}7 \times 10^{-9}$.

Radiation can be enormously reduced by polishing or plating the surface so that it reflects the rays instead of absorbing or radiating them (the two latter qualities go together). Paint, of whatever colour, has little effect, excepting aluminium paint, but a bright metal surface will have only about one-tenth of the above figure, whilst silver or chromium plating will bring it down to about one-twentieth.

Combining the above figures, for working temperatures of about 150° F. and surrounding temperatures of 60° F., the total loss from a rough iron pipe running horizontally in free air will be 2·5 B.Th.Us. per square foot per hour (or 0·73 watts per square foot) for each 1° F. temperature difference. Just about half of this is convection and half is radiation.

The above figure is for $\frac{3}{4}$-in. bore pipes and will be approximately correct for other small sizes. For a bare tank of any shape having a similar surface, or for a vertical

pipe, the figure will be 0·63 watts per square foot per 1° F. difference, for the same approximate working temperatures. A galvanised surface will show a lower figure, whilst plating the surface will reduce the loss to half.

Tank Lagging and Losses. The above has referred to the losses from bare metallic surfaces. The next step is to see how these losses can be reduced in the case of heater tanks. Gases are actually the best non-conductors, but their ease of movement makes them rapid carriers of heat by convection currents. The object of "lagging" a surface by means of heat insulating material is primarily to surround it with a blanket of air, which is prevented from moving through being imprisoned in the interstices of the material. The material will also intercept the radiation, and it must itself be a poor heat conductor, or it will nullify by conduction what it has gained through convection.

Almost any fibrous material will comply with the above requirements, and since excessive temperatures cannot arise there is a large field from which to choose. It is, however, advisable to have something which does not harbour insects and also something whose effectiveness is not entirely destroyed by small quantities of moisture. Granulated cork answers to this description, and is the material chiefly employed. When immersion heaters are fitted into existing tanks some cheaper material is often used, *e.g.*, corrugated cardboard surrounded by canvas, wood wool, sacking, shoddy, or any coarse clothing material.

As regards the thickness of the material, in the case of granulated cork as employed in the complete heaters a radial thickness of 2–4 in. is usual. A greater thickness than this would not save much additional loss, whilst it would add to the expense, and (more seriously) to the bulk, and therefore to the space required in the house.

The effect of a granulated cork lagging of the above

thickness is to reduce the losses to less than one-tenth of their value for a rough bare surface. In the case of a heater with a thermostat set to cut out at 180° F. and in at 170° F. it will be sufficient to assume a mean surface temperature of water container (when no water is being used) of 150° to 160° F. and a surrounding temperature of 60° F. The standby losses from the outside of the heater can then be taken as 4 watts per square foot, reckoning in this case on the total external surface area (*i.e.*, above the lagging). The above figure assumes a smooth, lightly finished exterior, and is typical of present-day heaters. Complete figures for all sizes are given in the frontispiece.

A consumer having a secondary or power rate of, say, $\frac{5}{8}d$. per kWh. can therefore be assured that the cost of the losses on a large heater will only amount to about 10*d*. a week. At this cost he has 20 gallons of nearly boiling water at his command at any time and without notice. If he goes away for a fortnight and forgets to switch it off, the mistake will cost him 1*s*. 8*d*. After paying this constant levy every drop of water he actually uses will be provided at 100 per cent. efficiency. Moreover, these figures refer to the extreme case, that of a heater connected to the mains and never used. As soon as hot water is drawn off, cold takes its place, so that in practice parts of the tank are at a lower temperature for considerable periods, and the losses are correspondingly less. Thus in the case of the 20-gallon tank the recovery time (with a 2 kW. heater) is 4 hours. If two tankfuls are used a day on the average (*i.e.*, 40 gallons of hot water a day), then eight hours will be spent in recovery, during which time the losses will average half their full rate. The result will be a reduction of four-twentyfourths or one-sixth of the stand-by loss. In the extreme case, if the water were used as fast as it became hot the working losses would be only half the values given in the table.

Instead of considering stand-by losses it may be

preferable to group these in with the consumption and to consider the overall efficiency of the process as a whole. Taking the same 20-gallon heater supplying water at 180° F. and with the standard loading of 2 kW., this would be capable, if used continually, of giving 125 gallons a day—*i.e.*, six complete tankfuls. When working at only one-sixth of this maximum output, and giving 20 gallons

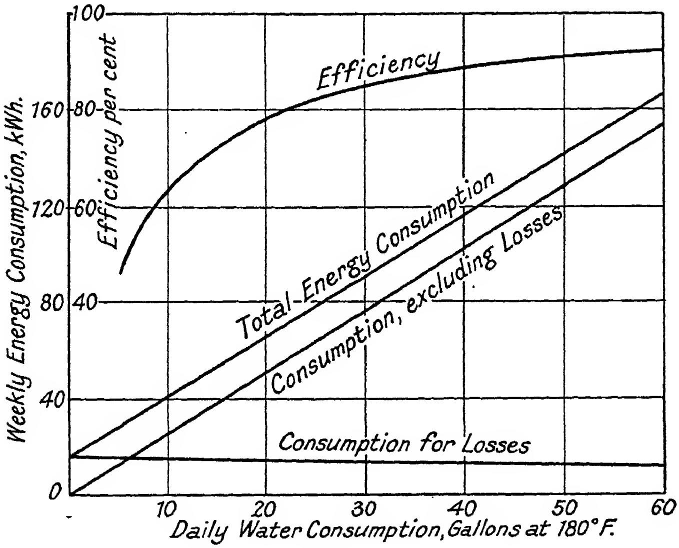


FIG. 3.

a day, the efficiency is 78 per cent. and 2·1 gallons of water at this temperature are given per kWh. These figures are illustrated in Fig. 3, showing consumption and efficiency to a base of output for the 20-gallon size. The high value of the efficiency, even on small consumptions, will be noticed.

Dimensions. The above notes have referred to the stand-by losses and their cost. There is another possible objection to the storage heater, and that is the space

which it occupies—depending on its shape and size. The best shape from the point of view of strength and minimum cooling surface would be spherical, but this would be very expensive to manufacture, and most inconvenient in the space it occupied. The next best shape for strength and cooling is the cylinder, particularly if the ends are not flat but domed slightly.[1] This is the shape most generally adopted, and usually the outer case follows the shape of the inner water container fairly closely, so as to leave a uniform annular space all round for the lagging material.

The best proportioned cylinder to give minimum cooling surface per unit of volume would be that in which the length equalled the diameter. This, however, would be inconvenient for space reasons, since usually the diameter is a more serious item than the length. An average of some six or eight manufacturers showed a length of outer cylinder 2·3 times its diameter, and this ratio was not greatly departed from by any of the makers or in any of the sizes. (This includes the extra length necessary to cover the terminal gear.) The position of mounting is almost invariably vertical in domestic installations, except in such cases as under-basin or under-sink heaters.

As regards the total volume of the outer cylinder, this has to include the actual water capacity, the space occupied by heater and thermostat elements, the top clearance in the case of displacement heaters, the heat insulation material and the various terminal and constructional features. The final results are summarised in the table in the frontispiece, and in the average just referred to, the cubical contents of this outer cylinder was found to be $1{,}300 + 600G$ cub. ins. where G was the water capacity in gallons. Since 1 gallon occupies 277 cub. in., it will be seen that the cylindrical space

[1] Comparing a sphere with a cylinder of equal volume whose length is twice its diameter, the cylinder will have 1·2 times as much cooling surface, but it will only have 0·7 times the diameter, and will therefore project less from the wall.

occupied by the heater is rather more than double its actual water capacity.

An alternative shape to the circular cylinder is the rectangular cistern. This is frequently adopted for constructional convenience in the case of " cistern "-type heaters, *i.e.*, those embodying ball valves. It is occasionally employed in displacement and pressure-type heaters, and is a common shape in the non-electric hot-water systems which are often required to be converted to electrical operation. A rectangular cistern is much less strong in resisting water pressure than a cylinder of the same gauge. It has also a slightly larger cooling surface for a given volume, but it takes up considerably less space and usually forms a more convenient wall fitting. Comparing a cylinder, having a length of two diameters, with a rectangular cistern of the same overall dimensions, the cistern holds 1·27 (say $1\frac{1}{4}$) times as much water and has $1\frac{1}{4}$ times the cooling surface.

Another advantage of the rectangular shape is that all three dimensions are independently variable and can be proportioned to suit the average mounting situation. A comparison has just been made between a cylinder of diameter 1 and height 2, and a cistern occupying the same space (*i.e.*, width 1, depth 1, and height 2) which proved to have $1\frac{1}{4}$ times the capacity. If this cistern is modified to have width 1·4, depth 0·7 and height 2, it will still have this capacity but the shape will be more convenient, since the depth is now half the width and only one-third of the height. The increase in cooling surface caused by this change in shape is only 5 per cent.

Heater Element. These are made in three general types, tubular, with removal cores, flat bladed, and the cement-filled pattern.

The removable core heater consists of a circular sleeve made usually in copper, but sometimes in steel or other

material, according to the purpose for which it is to be used. Into this sleeve is passed the heating core, which consists of a series of lozenge-shape refractories in the form of vertebræ, through which is threaded the heating wire spiral. A rod or rods passing through the length of the refractories holds them in position and enables the element to be withdrawn. The advantage of this type is that should a failure occur, the heating core or its element can be renewed without disturbing the vessel containing the liquid. The disadvantage is that considerable space is required to dissipate a given power.

The flat-bladed type heater consists of a flattened tube, either of copper, steel or other material, through which passes a flat type of heating element consisting of a resistance wire wound on mica and insulated with mica. This is threaded into the tube and is compressed when in position so as to secure good thermal contact between the element and the tube. (A group of removable core and flat-bladed heaters is shown in Fig. 4.) The advantage of this type is that a large loading can be accommodated in a comparatively small space, but the disadvantage is that should a failure occur it is necessary to remove the heater completely.

The cement-embedded type (Fig. 5) has become popular during the past few years. As its name implies, this has the element wire embedded in a special insulating and refractory cement, which gives the element a very high dissipating capacity, there being no air spaces to act as heat insulators. The element is in some types withdrawable from its sheath, but it cannot be repaired and needs replacement in the event of failure.

Most types of element can be run in any position, vertical or horizontal, and the loading per square inch can be altered to suit the various temperatures of water at different levels in the water heater if required. A recommended loading density is 10 to 12 watts per square

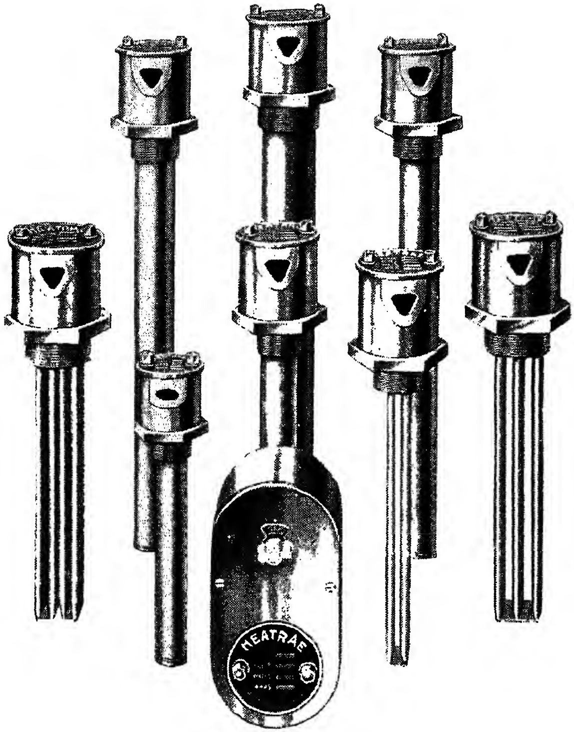


FIG. 4.—Heating Elements. Flat-bladed and removable (type.

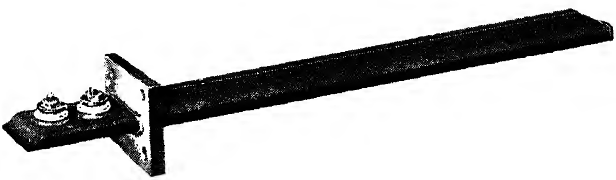


FIG. 5.—Cement-embedded Element.

To face page 36.

inch of element surface in hard water districts, but a higher figure is permissible where the water is soft.

Heater elements of these types, which are entirely immersed in the water to be heated, usually have one advantage possessed by no other type of water heater. With a fuel-fired boiler, geyser or other gas heater, the heating surfaces are to a very large extent rigid and inflexible. Rises in temperature during the heating process, although causing a general expansion of the boiler, do not result in sufficient movement of the heating surfaces to dislodge any scale deposited by the hardness of the water. In other words, the fur which is formed stays there, lowering the efficiency of the apparatus. With the electric heater, the immersed element is free to expand and contract, and to a large extent descales itself continuously. Many heaters in hard-water districts which have been opened up for descaling after five continuous years' use have been found with elements showing patches of bare metal and portions of scale shed from the heating surface lying at the bottom of the heater. This property is found to be present to a greater or lesser extent in all elements of this type, and it depends largely on the surface temperature of the element, the metal of which it is made, and its co-efficient of expansion together with the nature of the water hardness. The deposits obtained in the different districts vary from a soft sludge to a rock-like substance which seems to have the properties of cement. With the latter it is very hard to eliminate hot spots when the loading per square inch is high.

Immersion heater elements for use in existing tanks are similar to those described above. The internal construction is identical, but an exterior terminal cover is fitted in place of the apparatus plate and its cover. The combined immersion heater and thermostat shown in Fig. 53, on p. 128, is intended to simplify the installation of both pieces of apparatus. It must not, however, be

taken as an invariable rule that the thermostat will work successfully when in close proximity to the element, as some are designed to work under definite conditions, *e.g.*, vertically or horizontally and clear of circulating currents from the element.

Thermostat. This consists of two main parts, namely, the temperature-sensitive portion and the switch portion, the two being usually linked by some mechanism capable of magnifying the movement. As regards the former, the impulse needed to operate the switch is always obtained in the same way, namely, by the unequal expansion of two metals arranged side by side. This provides a relative movement with changes of temperature, the only difficulty being that the movement is a very slight one. A common arrangement is a solid rod of one material surrounded by a tube of the other material, the two running together up the middle of the heater. The top ends are rigidly connected so that the relative movement is experienced at the bottom. (A vertical arrangement is here assumed, but a horizontal arrangement is equally effective.) One of the materials is almost invariably "invar," a nickel-iron alloy (approximately 36 per cent. nickel), having practically no change of length with temperature. The other material is frequently brass, having a coefficient of linear expansion of 0·0011 per cent. per 1° F. A length of 1 ft. will therefore provide a relative movement of 0·002 in. for a 15° differential. Another arrangement is to employ the two materials as flat strips side by side and joined together at both ends. A small expansion then causes considerable bending but without sufficient strength to operate a heavy switching mechanism. This arrangement is therefore more suited to the solid contact switch.

There are two types of thermostat switch in use in water heaters, namely the mercury tube and the solid contact type. The former has been the most generally

employed in the past, and is still preferred by some makers, particularly for D.C. circuits, but the solid-contact type has to a considerable extent displaced it for A.C. work. The advantage of this latter type is that it works with a very small gap, and so requires only a small movement. It therefore dispenses with some of the magnifying gear necessary with the mercury switch. In order to work satisfactorily with so small a gap, some arrangement must be made to give a "snap" action on make and break. Heavy contacts must also be provided, so that they will

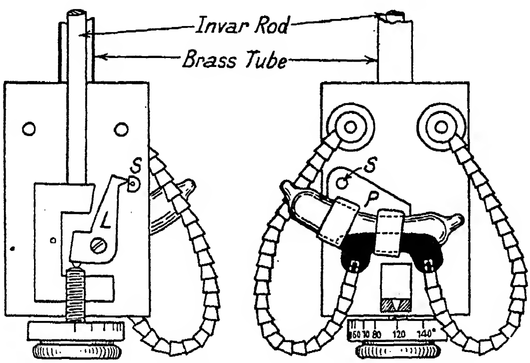


FIG. 6.—Front and back view of Mercury Thermostat.

quench the arc by their cooling action. On an A.C. circuit the current will then usually die out at the zero point after the first half cycle, but on a D.C. circuit no assistance is obtainable from this, and the breaking capacity is then very much smaller. It can, however, be improved by connecting a condenser across the switch contacts, this being omitted on A.C. circuits.

The mercury switch will usually not work satisfactorily with a differential of less than about 15°, but the solid contact type will work with 10°, or even down to 5°, differential. There is, however, no great advantage for water-heating purposes in having a closer differential

than 15°. A disadvantage of the mercury type is that it must be mounted in exactly the position (horizontal or vertical) for which it is designed.

Fig. 6 shows front and back views of a mercury thermostat. The expansion of the brass tube causes the invar rod to tighten, and thus lift the adjusting screw shown. This rocks a bell-crank lever L, which turns the spindle S. At the other end of this spindle is mounted a small plate P on which the mercury tube is cradled by a pair of clips. Regarding the right-hand view, the effect of temperature rise is to give a counter-clockwise movement to the plate, and this tilts the mercury to the left, and so breaks contact. Trouble has sometimes been experienced with deposits in the tube, and it is advisable for mercury to cover both the contacts leading into the tube, so that the current break takes place entirely between mercury. The space above the mercury is filled with an inert gas, such as argon, which serves to quench the arc on breaking. The brass tube may be directly surrounded by the water of the heater, or it may fit into a larger tubular pocket projecting into the heater. The latter arrangement has the advantage that the thermostat can be withdrawn without emptying the heater.

Fig. 7 shows a solid-contact type of thermostat operated by a bi-metallic strip. The invar portion of the strip is on the outer side, so that when the temperature falls the other portion contracts and the curvature of the strip increases. This brings the contacts closer together, and when they are nearly touching, the pull of the horse-shoe magnet finally snaps them together and so completes the circuit. On a rising temperature, the strip tends to move away, and this is resisted by the pull of the magnet. When the strip exerts sufficient force, the magnet pull is overcome and the contacts then spring apart to the full extent permitted by the stop. This stop is omitted in the diagram, and it is arranged to give a gap of about $\frac{1}{10}$ in.

It will be seen that the effect of the magnet is to accelerate the closing and to retard the opening of the contacts, and in both cases to ensure a snap action when the movement actually occurs. There may also be some degree of magnetic blow-out effect.

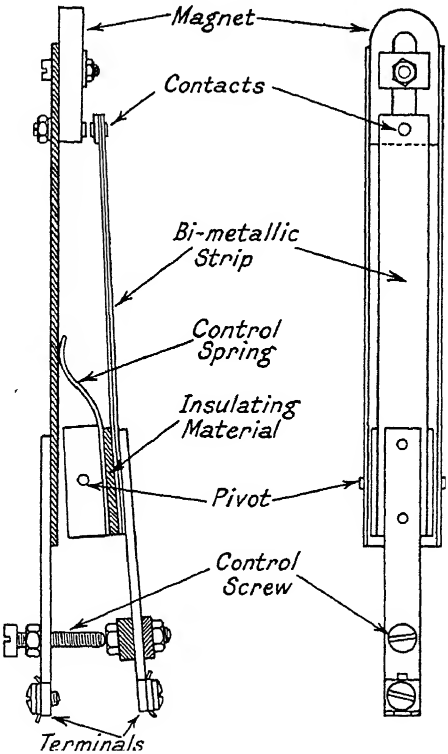


FIG. 7.—Solid-contact Thermostat.

The bi-metallic strip is mounted on a base which swivels about a pin, and is kept in position by the bottom adjusting screws acting against the flat spring above. Adjustment for temperature setting can be made by altering the position of these screws. Since the circuit, when completed, passes through the strip, there will be

some heating of the strip by the current. The effect of this will be to lessen the differential when the heater is actually working.

Scale. Water, as it occurs in nature, is seldom pure H_2O. Even rain water, although it has so recently been purified by evaporation and condensation, acquires salts and impurities from the air as it falls. In streams and ponds it soon becomes contaminated and dirty, and unfit to drink. By the time it has filtered through to deep springs and wells it has been freed from suspended matter and organic contamination, but it has taken up considerable quantities of dissolved salts. These salts account for what is known as the "hardness" of normal domestic water, as evidenced by the hindrance to the lathering of soap.

The dissolved salts are chiefly those of calcium and magnesium, and some of these, particularly calcium carbonate ($CaCO_3$), are retained in solution owing to the presence in the water of atmospheric carbon dioxide (CO_2). When such water is raised to boiling point, or nearly so, the CO_2 is dispelled and the $CaCO_3$ is deposited. This deposit is known as "scale," "fur," or "boiler crust," and may be in the form of a hard stone-like encrustation, whitish in colour, surrounding the heater element, the outgoing pipe, etc. If the water is boiled off, the other dissolved salts (magnesium and calcium chlorides and sulphites) are also finally deposited. Hardness which is due to the first type of salt and which is removed by boiling is known as "temporary hardness," to distinguish it from the other, or "permanent hardness." It is the former, of course, which causes the trouble in electric water heaters.

Water with much temporary hardness is often softened by adding sufficient milk of lime to combine with the excess of CO_2. The salt then solidifies out in the form of a precipitate and does no further harm. But water

softeners do not often form part of the ordinary domestic installation, and scale formation is therefore inevitable.

Water as obtained from the supply authority's mains varies greatly from place to place, and sometimes also with the time of year. It is usual to speak of soft-water districts and hard-water districts, although there is no precise dividing line, but rather a continuous range from the very soft to the very hard. Moreover, this division omits the essential distinction (from the present point of view) between temporary and permanent hardness. Water drawn from deep springs and wells is usually hard, whereas upland water from moors, lakes and mountain streams is soft. River water has only an intermediate degree of hardness, mostly of a permanent character, and therefore not deleterious.

Soft water frequently contains traces of acids having a corrosive action on lead, iron and zinc. It is on this account that copper cylinders are generally employed on hot-water systems in soft-water districts, such as Manchester, in preference to the galvanised-iron cylinders and tanks common in London.

Water hardness is expressed in degrees. In the Clarke scale, 1 degree represents 1 grain of dissolved salt per

	Temporary.	Permanent.	Total.
Torquay	0	1½	1½
Manchester	½	1½	2
Portsmouth	2½	14½	17
Northampton (Reservoir) .	3	3	6
Basingstoke	3	11	14
Carlisle	4	3½	7½
Brighton	9	5	14
Newcastle	10	4	14
Hull	12	5	17
London	13	5	18
Northampton (Wells) .	16	0	16
Yeovil	16	5	21
Hartlepool	25	17	42

gallon of water. Water with a total hardness of 5 degrees or less would be regarded as soft, whilst those with 12 degrees or over would be considered hard. The list of towns (given on page 43), arranged in the order of their temporary hardness, will give some idea of the variations encountered throughout the country.

Scale and Temperature. Figures published by the National Radiator Company from tests taken in their laboratories show that it is not necessary for water to be nearly at boiling point in order to deposit its temporary salts—in fact, about a quarter is deposited at 140° and nearly a half at 160°. The following table gives the average test results on water from eight different districts. It shows the deposit at various temperatures as a percentage of the total temporary hardness.

Percentage of Total Temporary Hardness Deposit obtained on:—

Boiling for ½ hour.	Heating to—				
	200°	180°	160°	140°	120°
99·5	77	63	45	25	8

It will be seen that only with temperatures of 120° and under can the furring tendency be regarded as negligible. At the top setting for water heaters (say 195°) it is about three times as great as at the bottom setting of 140°. Another point which appears to emerge from the tests taken is that with the harder water a bigger *proportion* of the total deposit is obtained at any given temperature. Thus at 160° the average deposit was 45 per cent. of the total. But the individual figures ranged from 25 and 30 per cent. to 60 and 70 per cent., the latter figures being obtained chiefly with the harder samples of water.

Manufacturers have dealt with the difficulty arising

from the effects of hard water upon heating surfaces in various ways. A frequent practice is to set thermostats to a temperature not higher than 170° F., especially in hard water districts. At the same time, the number of

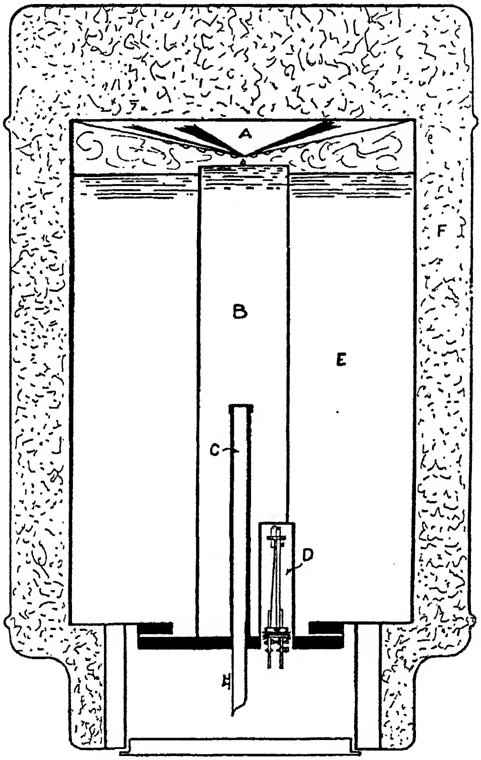


FIG. 8.—Secondary Heating for Scale Prevention.

watts per square inch of heating surface must be kept at a fairly low figure, otherwise ebullition on the element surface will take place, and hard scale will be deposited thereon.

The principle of secondary heating has been adopted in the "Densacone" water heater, shown in Fig. 8. In this case, the element C is immersed in distilled water B

kept replenished by condensed steam from the cone-shaped top A of the storage chamber. The amount of heat emitted per square inch of heating surface is thus kept very low and spread over a large area. Serious scaling can thus be practically eliminated, even in very chalky districts, but effective storage is reduced. It will be noted that the thermostat D is affected partly by the water in the inner container and partly by that in the outer chamber E.

Tank Material and Corrosion. The early electric water heaters had interior cylinders made of tinned sheet copper with soft soldered seams and were not able to stand more than a few feet head of water pressure. Later it was seen that interiors would have to be more rigidly constructed if the effects of higher pressures, expansion and contraction, etc., were to be overcome. The general practice nowadays is for the interior to be constructed from hard-drawn copper with soldered or welded seams, the whole being tinned by the hot tinning process or sometimes by electro-tinning. The tinning is, of course, to prevent corrosion of the copper by action of the water. This point is, however, by no means definite, as it has been held by some that tinning is only a preventive under certain conditions, and that corrosion is inevitable with some water supplies and particularly at the air and water level.

Baffle. All water heaters (with the exception of the cistern type with restricted feed) have to be fitted with some device to prevent the incoming cold water mixing with the hot water already contained therein. The position of the cold water inlet governs this to a large extent. In displacement and pressure heaters the inlet enters from the bottom of heater and if no deflection were given to the flow of water (*i.e.*, in an upward direction) not only would mixing take place but the cold water

would be inclined to " bore " through the cylinder in a straight line to the heater outlet (see Fig. 54, p. 129). Cold or tepid water would then be drawn off, and there would also be irregular working in the case of vertical thermostats. The usual way to prevent this is by placing a baffle in the form of a metal disc or semi-spherical cup directly over the inlet, which deflects the water in a downward direction (Fig. 9).

In cistern types of heater the inlet from the feed cistern may be taken through the lagging to the side or base of the container, where a baffle can be fitted at this point. Alternatively, the cold feed can be taken direct from the cistern through the top of the container, terminating in a downward direction within an inch or so from the bottom, and the cold water enters the container in a similar way. This system is however not so general. With immersion heater installations some type of baffle should be fitted if none exists, as described in a later chapter.

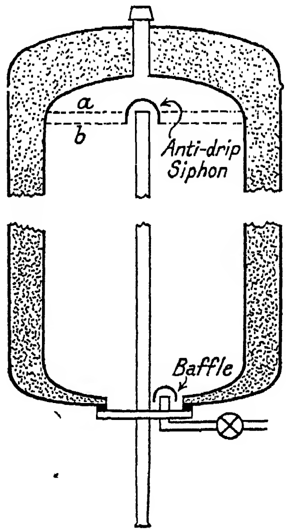


FIG. 9.—Baffle and Anti-drip Device.

Fig. 10 illustrates graphically typical performances of water heaters when correctly baffled. The graphs show the temperature of the water drawn off gallon by gallon, and going up to or even beyond the full capacity of the container.

It will be noticed that in the case of the self-contained heaters the temperature remained almost at the full setting point until half the capacity had been withdrawn, and it did not fall rapidly until 80 per cent. had been taken.

The immersion heater installation with rectangular tank showed an appreciable fall right from the first; had it not been baffled, the fall would have been much more marked in the early portion although less steep later.

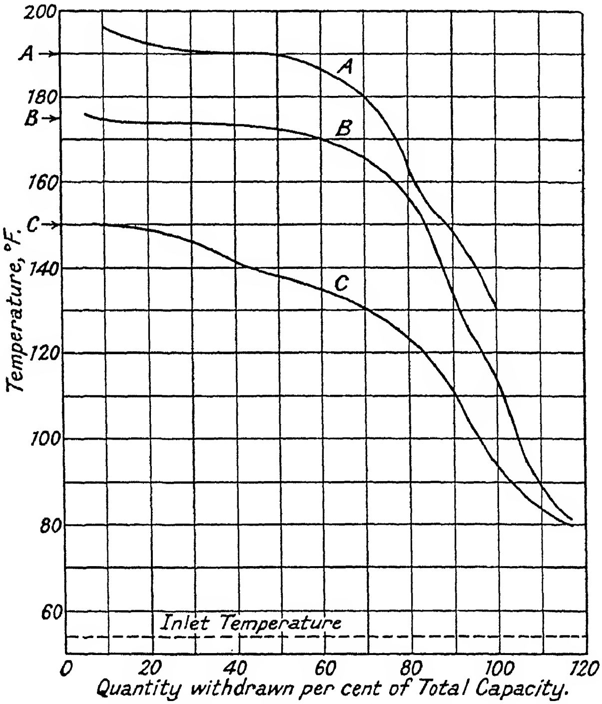


FIG. 10.—Withdrawal Temperatures.

(A) Self-contained cylindrical water heater, 10-gallon capacity.
(B) Self-contained cylindrical water heater, 22-gallon capacity.
(C) Immersion heater in 25-gallon rectangular tank (size 24 × 17 × 17 with baffled inlet).

Circulators. One refinement in design, calculated to overcome one of the disadvantages of thermal storage, is a means by which the water heated by the element is immediately passed upwards to the top of the storage container. This enables a quick recovery of the heater

so that small quantities of reasonably hot water can be obtained within a short time after the heater has been entirely emptied. Without some device of this kind, and especially in some types of heater, the circulation of water around the element is such that the whole bulk of the storage is raised uniformly to its final temperature.

Quick recovery can be secured by shrouding the element by means of a vertical tube which is usually heat-insulated to a certain extent by a second tube outside it with air in between. Another type works on similar principles, having horizontal elements with a vertical flow pipe, the whole being fitted inside the storage cylinder. Yet another (used principally for heating domestic cylinders) is connected to the external flow and return pipes.

When the water is hard, devices such as the above should be used with caution, as there is a possibility of their becoming completely choked with scale.

The fitting of the element heater in a vertical position also gives it to some extent a quick recovery of small amounts of hot water provided that the element is nearly as long as the vertical heating space. In order to allow for the different temperature levels the element can, if necessary, be loaded more heavily at the bottom than at the top; and where hard water prevents the use of a circulator this arrangement is a good second best.

A later invention is in the form of a circulator fitted with a thermostatically-controlled flap valve at the top or hot water outlet of the tube containing the elements. On switching on, a small quantity of water is quickly heated to say 140° F., when the flap opens, transferring the hot water to the top of the storage cylinder. The cold water which enters the circulator in place of the hot closes the flap valve again, following the same cycle of events, and so on.

Anti-drip Devices. These are found to be necessary in displacement water heaters in order to deal with the increased bulk of water at the higher temperatures. As explained in Chapter V., water expands when heated, and unless provision is made for this, the water will escape from the heater at the same rate and will be discharged at the open outlet in the form of a steady drip with consequent annoyance and inconvenience to the user. Nearly half a gallon would be wasted in this way by a 12-gallon heater in the process of heating up to 190° F. Anti-drip devices are designed to conserve this waste in various ways, which will now be described.

The most generally used anti-drip device is the siphon type, which consists of a dome or closed tube fitted over the top of the stand pipe as shown in Fig. 9. When the water heater has been used, and at the moment the stop valve is closed, the level of the water inside the heater is at " a." Siphonic action then reduces the level of the water to " b " when the siphon is broken by air drawn in at this point. The subsequent heating causes the water to expand and the distance between " a " and " b " is calculated so that whatever expansion takes place the water level will never rise higher than "a ". This type is found in a very large number of heaters. A similar result is obtainable by simply bending over the top of the stand pipe, as indicated in Fig. 11.

A very effective anti-drip device used in the smallest " Densacone " water heater makes use of a special cylinder within the heater in conjunction with an injector operated by the incoming cold water. On opening the stop valve the force of the water entering and passing through the injector draws a quantity of the water from the same cylinder which mixes with the cold water and is returned to the heater. On closing the valve the water in the heater percolates back again through the injector into the now empty cylinder which, as it fills, lowers the

level of the water in the heater to a sufficient level below the stand pipe.

It should be said that in spite of these and other devices it is extremely difficult to ensure that dripping shall never take place from an open outlet heater, and for this reason many authorities prefer a pressure to a displacement type, even where only one point has to be served. Another slight disadvantage is that most anti-drip devices result in a certain amount of hot water flowing after the tap has been closed. Unless this is allowed for by the user it may cause embarrassment, or at least be wasted.

General Design Features. Some water heaters are constructed with internal parts of considerable length. It is highly important therefore to verify that sufficient space underneath is available for future cleaning or repairs involving the withdrawal of such parts. Ease of removal of the apparatus plate and its various components (even when badly furred up) is another point which must be scrutinised.

The position and length of the element and thermostat play an important part in the working of the water heater. Generally speaking, the majority of manufacturers of self-contained water heaters favour vertical elements and thermostats on account of the neatness of the design possible therewith. The long element makes for a low wattage per square inch and has to a certain extent a circulatory action, giving a more rapid recovery of small amounts of hot water than a shorter element of equal loading. The long thermostat rod ensures more precise working, and though sluggish on closing it opens with precision when the whole of the water is raised to the predetermined temperature. On account, however, of the awkwardness of the withdrawal of such length elements and thermostats, some water heaters are designed with two shorter elements and moderate length ther-

mostat. Alternatively, a horizontal element may be fitted.

With water heaters for use in hard-water districts special attention has to be paid to the distance between element and thermostat and other internal parts. As mentioned previously, the contraction and expansion of the element produces some descaling action on the element exterior, and scale which has been displaced may fall and lodge between the element and adjoining pipes, only to trap further scale. The horizontal element eliminates the possibility of dislodged scale building up around the base of the element in this way. On the other hand radiation losses from the element and thermostat apparatus plate will be higher, and may necessitate lagging of the cover thereof.

CHAPTER III

TYPES, OPERATION AND LAY-OUT

THE notes in this chapter refer (unless otherwise stated) to self-contained heaters of the thermal storage type, complete with element, thermostat and lagging.

Sizes. British water heaters are rated in gallons, foreign water heaters usually in litres, which accounts for such odd sizes as 11 gallons (50 litres), 16½ gallons (75 litres) being found on old installations. British manufacturers have standardised their sizes of water heaters so as to cover as fully as possible the various uses to which they will be put. These standard sizes are as follows : 1½, 3, 5, 12, 15, 20, 30, 40 and 60.

Sizes 1½ and 3 gallons are for supplying sinks and hand basins in the normal sized house, whilst the 5-gallon size is for similar service in hotels and institutions. The 12-gallon size is the smallest possible for bath supply, and this and the 15-gallon size are the most popular installations for small and medium-sized houses. The 20- and 30-gallon sizes are for larger households; both capital cost and space considerations prevent their use in many cases. Still larger sizes may be employed in boarding houses, etc., or for night storage installations.

In order that prospective consumers shall be correctly advised as to the most suitable size and type of installation it is important that the installation engineer, like his colleague on the sales side, shall be a thoroughly competent specialist. Moreover, the two must operate in close conjunction, although where the one finishes and the other takes up the work will depend on circumstances. Once the seed has been sown, and an enquiry has resulted,

the first visit of inspection must be made. Reasonable time should be allowed on this visit to go into all details, since the consumer's requirements together with the installation technicalities will have to be ascertained.

The first query should be of the number and time of baths required daily and the number in succession. The type of system at present in use (if any), together with its capabilities and defects, should also be discussed. This last is of great importance, as a few words from the consumer on this subject will prove extremely helpful and will probably include many details of the habits and requirements of the household. Some inkling of the family budget and of the amount that can be spent on the hot water service will also be of service.

The next step is a complete examination of the existing water system of the premises, both cold and hot. With the information thus collected, and the data given in the present chapter, it should be possible to make the appropriate recommendations.

As regards size, warning should be given against taking at their face value statements made as to the number of baths required in succession. These may be based on the idea of a weekly "bath night," once a necessity and now become a habit. An adequate electric hot water service means a hot bath at any moment without notice, but not a string of hot baths on one particular night. Consumers must therefore be willing to space their demands somewhat if they are not to have a heater too bulky and too costly for their liking.

Displacement Type. This, which is also known as the "non-pressure" or "push through" type, is probably the simplest form of water heater made, and simplest also in its installation. It can best be described as a lagged cylinder arranged with a cold water inlet at the base controlled by a stop valve (A, Fig. 11) which, when opened, causes the heated water contained in the cylinder to be

displaced by the incoming cold water. The hot water overflows down a stand pipe from the upper part of the cylinder and so through the open outlet D, so long as water is flowing into the heater. On closing the stop valve at the inlet of the heater the displacement of hot water ceases and the flow at the open outlet stops. Heating element and thermostat C are usually fitted near the bottom of the cylinder.

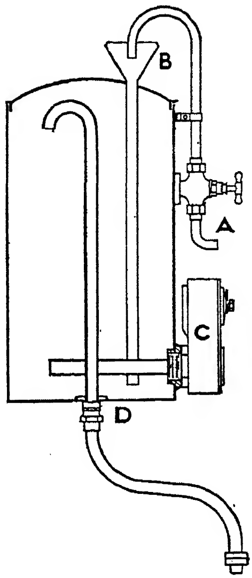


FIG. 11.—Broken Feed Displacement Heater.

The non-pressure heater is used where hot water is required at one point only (Fig. 12), but two points, such as an adjoining bath and lavatory basin, can be supplied by one heater fixed midway between the two and fitted with a swivelling spout to discharge hot water into either (Fig. 13).

Installation of a displacement type heater is usually a very simple affair. Since the outlet is always open, no pressure can develop in the heater and no expansion or vent pipe is needed. In many cases the supply can be run direct from the full pressure main, which will usually be already serving a cold tap at the same sink or some adjacent point (Fig. 12). Only a few feet of piping will then be required, and a further advantage will be that water from the heater can be

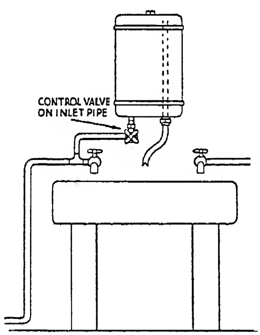


FIG. 12. — Displacement Type Heater.

used for drinking and culinary purposes without fear of contamination from a cistern (such cisterns may be situated in a dusty attic and seldom or never cleaned out).

Some water authorities object to a mains supply on the ground that the main is occasionally cut off, and if the heater tap were opened during such a period the heater would drain back into the water main, causing a burn out of the heater element (unless the thermostat operated), and possibly fouling or carrying steam into the main. Another objection is to the heavy and uneven demands on the mains due to direct bath supplies. Whatever may be thought of these arguments, there is little possibility of appeal in the matter, and it is necessary to comply with the requirements of the particular water authority. Some authorities allow direct connection to their mains of all sizes of water heaters, others restricting direct connection to the smallest sizes or forbidding it entirely.

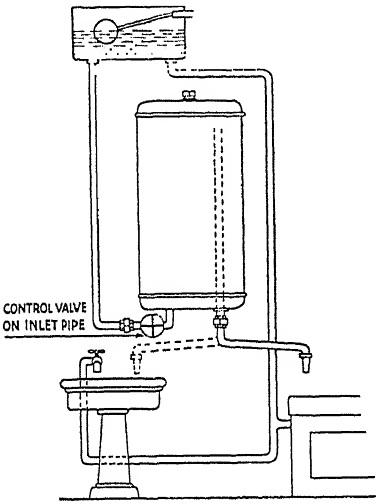


FIG. 13.—Displacement Heater Installation.

Where exception is taken to a main feed of this kind, there are two alternatives. One is to take the feed from a cold-water cistern situated above the level of the top of the water heater (see Fig. 13). This ensures a definite break in the continuity of the feed and leaves no possibility under any circumstances of water running back

from the heater into the cold-water main. Another way of ensuring this is achieved by use of a special type of water heater fitted with a funnel, or "broken" feed (see Fig. 11). The heater can then be connected direct to the cold-water main, but this, while conforming to the regulations of most water authorities, is not accepted by some, who insist on feed tanks. There is also the possibility of water splashing over the funnel if turned on too hard on a high-pressure main. In some instances, non-return valves are allowed, to prevent the back-flow of water into the mains, but these are not generally looked upon with favour.

As regards size, a supply pipe of ½-in. diameter bore is sufficient for heaters of 12-gallon capacity or under, and the 15-gallon size can also be included, provided the head of water under which they will work exceeds 10 ft. Otherwise, ¾-in. bore is recommended, in order to obtain an adequate supply when run off a cistern at a low head.

As regards the outlet pipe, usually the heater is mounted close to its job and a fixed or swivelling spout on the heater forms the outlet, and saves further plumbing. Sometimes this spout is connected to an ordinary tap with the jumper and washer taken out, but this practice must be deprecated, as sooner or later the misguided "handy man" may replace the jumper, putting the water heater under pressure until trouble develops and damage is done.

Displacement type heaters are particularly useful in flats and similar situations, as they can be fitted without disturbing tenants either above or below. In addition to low installation costs, they have the advantage of little or no heat losses from piping, etc. They have, however, certain disabilities, and even when only a single hot supply is needed, one or other of the following reasons may necessitate the employment of a pressure heater instead :—

(1) Water authority will not allow this type. (Some authorities definitely forbid the connection of non-pressure water heaters above 5-gallons' capacity, on account of the possibility of waste through dripping.)

(2) Insufficient space to fix heater where it can discharge direct into bath, or fixing impossible (marble walls, cupboards above bath, no wall space owing to windows, etc.).

(3) Objection to dripping on behalf of user.

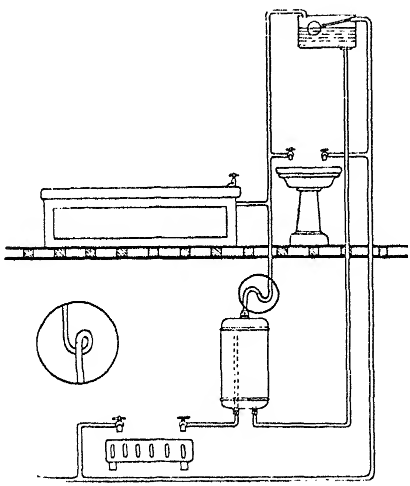


FIG. 14.—Semi-pressure Installation.

(4) Heater required fitted out of sight (in cupboard, etc.).

(5) Hot water required for bath primarily, but with possibility of extending later to other taps.

Pressure Type (sometimes called "semi-pressure"). This type of water heater has been designed to work in a similar way to the ordinary domestic hot-water cylinder or tank, and is intended for installations supplying two or more points (Fig. 14). It differs from the displacement type in the following particulars, which are dealt with in greater detail below. Instead of having an open outlet, the whole system operates under a certain amount of pressure, and the control taps are on the outgoing points (as in an ordinary hot-water system), not on the incoming pipe. A vent pipe is essential, and this frequently adds to the installation costs.

Dealing first with the water supply, it must be pointed out that the pressure type of water heater, although

sometimes tested to and capable of withstanding fairly high pressures, cannot be connected direct to the cold-water main and worked under the full mains pressure. Although such a system of connection prevails on the Continent, practically every water authority in this country prohibits it as being not sufficiently foolproof.

The inlet will, therefore, have to be connected to a low-pressure or tank supply (*i.e.*, from an open ball-valve cistern), preferably by a separate pipe running directly from the cold cistern itself. This means that under all circumstances the heater can be relied on to run at full force without restrictions such as are occasioned when other taps connected to the same pipe are operated at the same time. Alternatively, a large-bore pipe can sometimes be found in near proximity and a supply may be obtained from it, and care should then be taken to prevent the emptying of the heater, as described in the next chapter.

It is, of course, essential that the cistern water level shall be above the top of the heater and also above the highest hot point served. When the cistern is at the top of the house, no difficulty will arise in obtaining sufficient pressure. When the cistern is on the same floor, however, there may be only 1 to 4 ft. between its water level and the top of the heater. In these cases it is essential to have the inlet pipe from tank to heater at any rate equal to, and for preference greater than, the bore of the outlet or hot-water distribution pipe. In any case, this inlet pipe should never be less than $\frac{3}{4}$-in. bore, and should be controlled by a gate valve, for convenience of overhaul and washer renewals.

The second point of importance is that all pressure-type installations must have a vent or expansion pipe running from the top of the heater and having a free outlet at the upper end. This allows any air or steam to escape, and ensures that under no circumstances can pressure

develop beyond that represented by the head of the cistern. Safety valves are not reliable enough for this purpose, and are not accepted by water authorities in this country. The same pipe can be used for supplying hot taps, but it should, if possible, rise steadily throughout its run to prevent air accumulations. At the top end, this pipe is usually bent over the top of the cistern, so as to discharge into it in the event of steam or water blowing off.

When the expansion pipe is used solely for venting purposes, it need not be larger than $\frac{1}{2}$ in., but when it also supplies hot points it should be at least as large in bore as the biggest tap supplied. A large-diameter pipe of this kind, specially if it runs vertically upwards for a considerable distance, will result in certain heat losses. Apart from any water being drawn off, there will be a certain circulation of hot water up the centre of the pipe and down the (cooler) sides. This can be prevented by putting a loop or S-bend in the pipe as close as possible to the heater, as shown by the circles in Fig. 14. The objections to such a practice are the space required, the unsightliness and the liability to fur up at this point. Tests have shown that the losses on this score are seldom great, and it is doubtful whether the practice is justifiable.

In a large number of cases, especially in small property, the bathroom is on the upper floor, and the expansion pipe can be carried out with reasonable ease and without great cost and inconvenience. But in premises that have been sub-divided into flats, the lower apartments may bring some difficulties. Permission to carry out work in property other than that occupied by the consumer is often difficult to obtain or is flatly refused, so that alternative suggestions must be available. The case can be met by either a cistern-type water heater, to be dealt with later on, or by fitting a new storage cistern within the limits of the consumer's premises. The position for

this should be as high as possible (not forgetting to allow 9 to 12 in. above, to allow for repairs to be carried out to the ball valve); and as centrally disposed as possible, to reduce the pipe-work to inlet of heater and expansion pipe from same. However, the distance to an existing water pipe from which supply can be obtained, and the necessary overflow pipe must also be taken into account.

Hot water from the pressure-type heater, as from other types, must be taken from the top of the water. There are usually two outlets provided, namely a top outlet for the expansion pipe, and an outlet coming out at the bottom but fed by a vertical stand pipe running inside the heater and taking water from the top. This latter outlet can be used for any taps situated below the heater, whilst the former is used for all higher taps, which are usually taken straight off the expansion pipe itself.

In Fig. 14, both the above-mentioned outlets are being used, but this is purely a matter of convenience, being determined by the position of the heater with regard to the points to be supplied. At times, all the taps may be connected to the top outlet, which is continued and terminates as the expansion pipe, the bottom outlet being plugged off and left unused. This case often arises when a heater is fitted on the ground floor in a position not close to any point where supply is required. Alternatively, when a heater is fitted over a bath, say, to supply the bath and basin and the sink on the floor below, the bottom outlet is connected to all points of supply, the top outlet, however, still being carried out as the expansion pipe. At no time is the top outlet of a semi-pressure water heater ever plugged or capped off, it must always connect to an open outlet.

Cistern Type. This is designed to overcome the difficulty of the cold-water supply when a low-pressure service is not available. As will be seen from the illus-

tration in Fig. 15, it is a combination of a storage heater with a small cistern having the usual open top and ball-valve. It therefore forms a self-contained system which can be connected directly to the high-pressure water main. Being usually rectangular in shape, it takes up little or no more space than a plain (cylindrical) heater of the same capacity: on the other hand, it usually has somewhat higher heat losses.

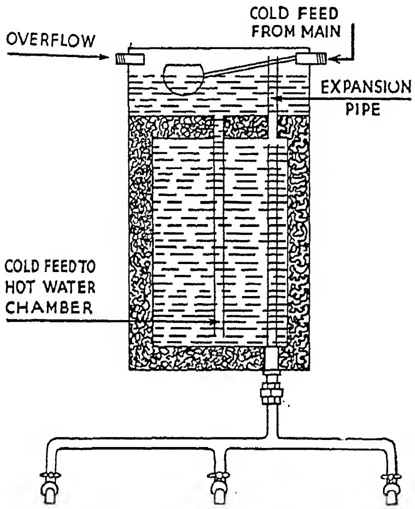


FIG. 15.—Cistern Type Heater.

Referring again to the illustration, it will be seen that the ball-valve tank is situated above the hot-water chamber, and heat insulated from it. A cold pipe runs from the tank to the bottom of the heater, and the hot service runs from the top of the heater to the hot taps. Another short pipe (expansion pipe) runs from the top of the hot-water chamber to a point above the water level in the ball-valve tank. The immersion heater and thermostat are carried on a removable plate attached to the bottom of the tank, and surrounding these is the tinned copper hot-water chamber.

The cistern type of heater is chiefly used in situations where separate cold-water cisterns are undesirable or impossible of accommodation; and it is the only type of heater serving two or more taps which can be connected direct to the cold-water main. It has one disadvantage, however, that the heater must, of necessity, be fitted

above the highest tap that it has to supply. This means that in many cases it cannot be fixed in the most central position for serving the various hot taps required. This point can become serious when, for instance, the bath, over which the heater must be fitted, is on a higher floor and not immediately over the kitchen, where the most abundant supply and the shortest pipe-work is particularly required.

A second disadvantage of the cistern-type heater is that, whilst a low-pressure supply and an external expansion pipe can be dispensed with, an overflow pipe has to be fitted. Such an overflow is a necessary corollary of any ball-valve cistern to prevent damage by flooding should the ball-valve stick. Moreover, this overflow pipe must fall throughout its length, and must be taken outside the building and not, as is sometimes seen, led back to a bath or sink.

Varying Volume Cistern Type. The heater just described, like the other types dealt with in this chapter, operates with a constant volume and varying temperature. There is another type of cistern heater, rather less common, which works at a constant temperature and varying volume.

The first type follows the usual hot-water principles of domestic installations and is actually a pressure water heater with feed tank above it. The water heater is, of course, always full, and the hottest water from the top of the storage cylinder is displaced by incoming cold water from the small feed tank. The second type is arranged so that the cold feed from the ball-valve tank at the top of the heater is restricted to a very slow rate. The flow is calculated at the rate it would take for the heating element *immediately* to heat the incoming water to a given temperature. It will be seen, therefore, that the heater is capable of supplying a small amount of hot water soon after the entire contents have been drawn,

since the hot water is supplied from a pipe connected to the *bottom* of the cylinder.

As recuperation takes place, the storage level of hot water rises until the whole cylinder is full, when the ball valve closes and current is automatically cut off. Unlike the first type, which continues to supply cold water at the same rate after all hot water has been drawn, the second type, when emptied, dries up to a mere trickle, which is equal, of course, to the rate at which cold water is being heated and fed to the storage cylinder. The disadvantage, however, is that the restricted inlet is very easily obstructed either by some foreign matter or by scale, and additional maintenance must be anticipated.

The Under-basin Heater. A useful combination of electric water heater and wash-hand basin is shown in Fig. 16. The heater is of 1½ to 3 gallons capacity displacement type and is installed under the basin or concealed in the pedestal supporting it. A combined tap and outlet occupies the usual hot-water tap position, and when this is turned, cold water is admitted to the inlet, displacing hot water up and out through the outlet. This outlet is, of course, always open and free, so that expansion can take place and no pressure can develop. It will be noted that the tap stem is continued down to the inlet valve, and when operated does not restrict or stop the outlet in any way.

The Unlagged Heater. A very simple form of heater for applying water to bath only, *i.e.*, one point of outlet, and suitable for connecting direct to the cold-water main, is shown in Fig. 17. It is sometimes preferred to the low-loaded type of heater kept continuously hot, particularly when only occasional baths are required at an hour or two's notice. The loading of the heater is 3 to 4 kW., and it can be fitted with a combined switch and immersion heater. It will be seen from the illustration that the outlet spout at the bottom is adjustable in position so

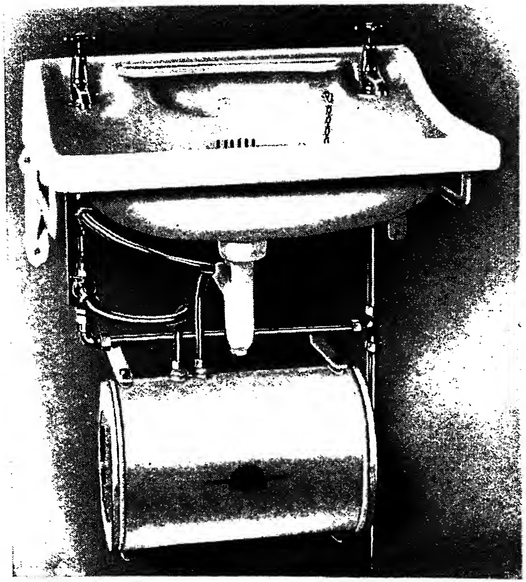


FIG. 16.—Under-basin Heater.

FIG. 17.—Unlagged Heater.

To face page 64.

that the heater can be placed on a bracket by the foot of the bath, the switch turned round to a convenient position, then the position of the outlet spout adjusted to discharge into the bath. In the case shown, a broken feed is provided, thus permitting direct connection to the water main. This heater is a displacement type, unlagged, and the water control is on the inlet. The method of working is to switch on the heater about an hour before a bath is required, then it is switched off and water turned on at the cold-water inlet. Thermostatic control is unnecessary, and a very simple heater results.

Wash Boiler. Fig. 18 shows an electric wash boiler such as is frequently installed in workmen's dwellings and tenements. It is unlagged, hand-controlled, and has a rating of 3 to 4 kW. and a capacity of 8 to 10 gallons. It is used for clothes-washing and for providing intermittent hot water for occasional bath and sink. For the latter purpose the water can be drawn off from a tap, or displaced by cold inlet, or even in some cases pumped up to a higher level. It is in no sense a hot-water service, but it forms a cheap compromise for those unwilling or unable to afford a complete installation.

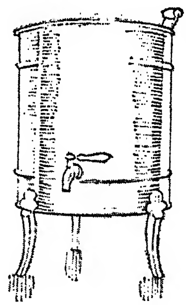


FIG. 18.—Wash Boiler.

Thermostat Setting. The thermostats used in water heaters are usually adjustable and can be set to operate at any desired temperature. The normal range of adjustment is from about 100° F. to 200° F., in steps of not less than 10°. Usually the scale marking refers to the cutting-out temperatures ; thus a thermostat set at 180° might cut in when the average temperature of the operating rod was 170° and cut out again when it reached 180°. Provided the tap is fairly close to the heater, water should be obtainable at the tap at about the same temperature as

the thermostat setting, even at a time just before the switch cuts in. It will be realised in this connection that the hot feed is taken from the top (*i.e.*, the hottest point) of the tank. The thermostat differential (difference between cutting-out and cutting-in points) is usually from 5° F. to 15° F. The reasons for this value are discussed in Chapter VIII.

The setting should not in any normal case be lower than 140° F., since it is desirable to have water at the kitchen tap at this temperature for washing-up and as a start in water-boiling operations. A higher setting is usually advisable, because this increases the effective capacity of the heater. On the other hand, as boiling point is approached, scaling becomes much more pronounced, and some steam may be produced. The usual recommendation is a setting of 170 to 180, with a minimum of 160 in hard-water districts and a maximum of 195 where the water is very soft.

The connection between temperature setting and effective capacity is illustrated in the accompanying table. Ten gallons of water are presumed to be stored at the temperatures shown in the first line of the table. When diluted with water at 54° F., they give the larger quantities shown in the lines below. Thus, if used at a kitchen temperature of 140°, they give quantities up to 16 gallons, or if at a bath temperature of 104°, up to 27 gallons, when the storage temperature is 190°.

Put in another way, a change in setting from 140° F. to 183° F. is equivalent to a 50-per-cent. increase in storage capacity, so that a 20-gallon boiler set at this upper figure is as good as a 30-gallon immersion heater installation at the lower setting.

10 Galls. stored at . .	140°	150°	160°	170°	180°	190°
Are equivalent at 140° to	10·0	11·2	12·3	13·5	14·7	15·8
or ,, ,, 104° ,,	17·2	19·2	21·2	23·2	25·2	27·2

A question which sometimes arises is as to whether it is better from the point of view of heat losses to have a larger capacity tank at a lower temperature, or *vice versâ*. The answer is that the former is preferable, and gives the smaller heat loss for a given heat capacity. This assumes that the extra-sized apparatus costs no more in the first place nor causes inconvenience through the space it occupies. The question therefore arises more particularly in choosing between an immersion heater installation and a complete boiler.

The reason for the above answer can be put in general terms as follows: if the ambient temperature (*i.e.*, surrounding air) is taken as identical with the inlet (cold water) temperature, then if the temperature rise above this datum figure could suddenly be doubled the effective heat storage of the tank would be doubled and the heat loss would be doubled also. On the other hand, if the temperature setting were unchanged and instead the volumetric capacity of the tank were doubled, the heat storage would again be doubled, but the surface, and therefore the losses, would only be increased by some 40 per cent.

The case may be put in general terms by saying that with any container of fixed proportions (*e.g.*, a cylinder whose length is a constant ratio of its diameter) increasing all the dimensions by 1 per cent. will increase the capacity by 3 per cent., but will only increase the surface (and therefore the losses) by 2 per cent. Whereas increasing the temperature rise by 3 per cent. will increase both the capacity and the losses by 3 per cent. (When the ambient temperature is above the inlet temperature, the ratio of 3 to 2 will be slightly exceeded.)

Comparing heaters of the same effective storage capacity, *e.g.*, a 20-gallon boiler set at 183° F. and a 30-gallon boiler or immersion heater set at 140° F., the latter will have about 15 per cent. less loss with the same quality of lagging.

The device of reducing tank losses by using a larger tank at a lower temperature setting is limited by the utilisation temperature even when it is not limited by size or price of apparatus. In practice, a temperature of 130°–140° F. is desirable at the kitchen tap, and since an upper limit of 180°–190° is set by furring considerations, it follows that the extreme range of possible action in this direction is represented by the two boilers compared above. (See also the detailed comparison on p. 119.)

Tank Cooling. The cooling of the tank after the thermostat has switched off (assuming no water is drawn off) follows the same lines as the cooling of a pipe, discussed below. But the case is somewhat simpler because the temperature is only allowed to fall by a few degrees so that the cooling is at a practically constant rate. The value of this rate will depend on the ratio between the dissipating properties and the heat contents.

With a constant thickness and quality of lagging the dissipation will be directly proportional to the external surface area and the temperature rise above the surroundings. An approximate figure that has been given for manufactured heaters is 0·04 watts per sq. ft. of outside surface per 1° F. temperature difference, or 4 watts per sq. ft. for a heater under normal working conditions.

Since the dissipation is proportional to the surface, and the heat contents are proportional to the volume, it follows that the rate of temperature fall will get less as the heater size gets greater. In the case of the $1\frac{1}{2}$-gallon size the surface is 5·7 sq. ft., so it will lose $5{\cdot}7 \times 4$ watts or $5{\cdot}7 \times 4 \times 3{\cdot}4 = 77{\cdot}5$ B.Th.Us. per hour. Since this contains $1\frac{1}{2} \times 10$ lb. of water the cooling rate will be $\frac{77{\cdot}5}{15} =$ (approximately) 5° F. per hour. A similar calculation shows the following approximate cooling rates in °F. per hour : 4 for the 3-gallon size, 2 for the 12-gallon, $1\frac{1}{2}$

for the 20-gallon, and 1·2 for the 40-gallon. Fig. 62 on p. 158 shows the cooling curves for a 20-gallon heater for several different thermostat differentials.

Heater Position. Three main considerations govern the position of the heater, namely, minimum obstruction, minimum installation costs, and minimum running costs through pipe-lines. As regards the first point it is obvious that the higher and more out of the way the heater can be put the better will the consumer be pleased. The second point concerns the general piping lay-out (which has already been discussed) and, to a lesser extent, proximity to the electricity supply. The third point requires some further consideration.

Heat losses will occur in all the outlet pipes from the heater to the hot taps. Furthermore, there will be the delay and annoyance in using a hot tap after a spell of disuse owing to having to wait while the dead water is being run off. The general principle of mounting is therefore to place the heater as near as possible to the tap having the most common use, frequency rather than magnitude being the deciding factor. Thus in the case of the consumptions scheduled on p. 140 the bath accounts for half the total consumption, but the kitchen would probably involve a much more frequent draw-off than bath and basin together. Even allowing for the smaller size of the sink pipe a kitchen site would then be preferable ; and, provided the run to the bathroom is not too long and the basin is not used too often, an economical result should be obtained.

If there is no room for the tank in the kitchen it must be fitted in the bathroom or at some intermediate point. It is then essential that the run to the sink shall be short, preferably not more than 10 to 15 ft. Better still would be to lag this pipe, but so often it is already inaccessible when the electrical scheme is planned, and even when it it not, the additional size may be objected to.

Pipe Losses. In the following calculations it is assumed that the ambient house temperature averages 60° F. and that water is drawn off at 180° F. from the top of the tank. There will be a temperature gradient in the pipe and walls, but it may be assumed that shortly after the tap is turned off the whole of the pipe walls and contents take up one uniform temperature. The value of this temperature (above the surroundings) is taken as three-quarters of that of the hot water drawn off, *i.e.*, it will have a 90° F. rise instead of 120° F. The correct value to be taken will depend largely upon how much water is drawn off, and in any case it must be a compromise since the water will be appreciably hotter than the outer pipe walls, and one end of the pipe will be hotter than the other. Tests taken have indicated the above figure as a representative assumption.[1]

Calling the surrounding temperature zero and reckoning all temperatures from this datum level, the rate of change of temperature at any moment will be proportional to the temperature at that moment. There is only one equation which has this property, namely, the exponential function of the form $y = e^x$. Hence the temperature θ at any time t can be calculated from the initial temperature θ_0 by the formula $\theta = \theta_0 e^{-Kt}$ where K is a positive constant. The rate of temperature fall is then given by $K\theta_0 e^{-Kt} = K\theta$. The constant K is therefore seen to be the cooling rate of the pipe surface per degree of temperature difference above the surroundings.

Now a small horizontal pipe having a dull rough surface loses approximately $2\frac{1}{2}$ B.Th.Us. per sq. ft. per hour per 1° F. temperature difference (see p. 30). Hence 10 ft. of $\frac{3}{4}$-in. iron pipe having an outer surface of 2·75 sq. ft. will lose 6·8 B.Th.Us. per hour per 1° F. difference.

[1] If water with a 120° F. rise were suddenly introduced into a cold pipe, the resultant temperature rise would be 57° F. with a $\frac{1}{2}$-inch pipe and 72° F. with $\frac{3}{4}$-inch. But as water continues to be drawn, this figure will rise.

Reckoning 11·3 lb. weight of pipe with a specific heat of 0·114 and 1·9 lb. of water contents, the heat stored in 10 ft. of pipe will be $11{\cdot}3 \times 0{\cdot}114 + 1{\cdot}9 = 3{\cdot}2$ B.Th.Us. for each degree F. Hence the cooling rate K will be $6{\cdot}8/3{\cdot}2 = 2{\cdot}1°$ F. per hour per 1° F. difference. For 90° F. temperature difference the formula for temperatures becomes $\theta = 90e^{-2{\cdot}1t}$ where t is in hours. In 20 minutes the temperature will have fallen to half its initial value, whilst in half an hour it will have dropped by 58° F. In an hour-and-a-half it will have lost all but 5 per cent. of its initial temperature rise and can be regarded as stone cold.

A similar calculation for a 10 ft. length of ½-in. piping having a surface area of 2·2 sq. ft., shows 1·9 B.Th.Us. stored per 1° F. rise, a fall in half an hour of 71° F., and a period of 1 hour to fall to 5 per cent. of its initial rise. It follows that the loss due to a single draw-off (after a lapse of an hour or so) is $3{\cdot}2 \times 90 = 300$ B.Th.Us. or 88 watt-hours for the ¾-in. pipe, and $1{\cdot}9 \times 90 = 170$ B.Th.Us. or 50 watt-hours for the ½-in. pipe. It will further be noted that unless the tap is used again within about 15 to 20 minutes the water left in the piping will only be at approximately 100° F. It will therefore be almost useless for kitchen purposes although possibly of service in bath or basin. (The contents of 10 ft. of ¾-in. piping is under a quart, and of ½ in. under a pint. This quantity of lukewarm water may be of use in diluting the hot water that follows, at least in bathroom service.)

Before these figures can be applied it is necessary to make some estimate of the cycle of use. Since no two households have the same habits and even in one household no two days are the same, little good can be done by measuring the losses in particular cases. Probably the best plan is to make a few quite arbitrary assumptions and to work out the theoretical heat losses. A rough idea can then be obtained of the limits between which the losses can be expected to lie in a likely case.

Consider first a 10-ft. length of $\frac{1}{2}$-in. pipe serving a kitchen sink. Assume that the tap is used for a six-hour spell in the morning (*e.g.* from 8 a.m. to 2 p.m.) and for a two-hour spell in the evening (say 6 to 8 p.m.), and furthermore that it is used exactly once every half-hour during these periods. The heat lost in a temperature fall of 71° F. will be $71 \times 1{\cdot}9 = 135$ B.Th.Us. for each one of the half-hourly draw-offs (16 in all) provided that the lukewarm water can be utilised. Assume also that there is a final draw-off at 2 p.m. and at 8 p.m., after which the pipe gets quite cold. The total will then be $16 \times 135 + 2 \times 170 = 2{,}500$ B.Th.Us. a day or 5 kWh. per week.

If the pipe water is useless after the half-hour interval the only credit that can be given for the previous use is the heat left in the pipe walls themselves. The consumption then will be 5·7 kWh. per week. A third possible assumption would be that the use of the tap during the eight hours was so frequent that the pipe was maintained at 150° F. (*i.e.* 90° F. above surroundings). The loss would then be $2{\cdot}2 \times 2{\cdot}6 \times 90 \times 8 = 4{,}100$ B.Th.Us., to which must be added the same figure as before for the two times when the pipe gets quite cold. The consumption on this latter supposition would then be 9·1 kWh. per week.

The conclusion is that, taking eight hours a day kitchen use of a 10-ft. length of $\frac{1}{2}$-in. pipe, the loss for the service mentioned will probably be between 6 and 9 kWh. a week, say $\frac{3}{4}$ kWh. per ft. run.

The alternative to this piping would be an additional heater mounted close to the sink. The losses on this would be about 5 kWh. a week, *i.e.*, the same as on 7 ft. of piping. The hire charge on such a heater would be, say, 4*s.* 6*d.* a quarter, and on a tariff of $\frac{5}{8}$*d.* per kWh. this charge would be equivalent to $6\frac{1}{2}$ kWh. a week, the same as the losses on 8 ft. of piping. The maximum economic length of piping for this service would therefore be $7 + 8 = 15$ ft., and if the kitchen run were more than

this it would pay to put in the extra heater. The above calculation can only serve as a rough guide, being exact only for the data given, and it assumes that the installation of the extra heater costs no more than the price of the piping saved. On the other hand it neglects certain incidental advantages such as the immediate response at the hot tap, and the possibility of using the water for culinary operations.

In the case of a bathroom service it may be assumed that when a tap (or an adjacent one) is re-employed a few minutes later no further loss occurs, so that several uses of a hand basin in rapid succession will rank as one draw-off. On this basis, and assuming a $\frac{3}{4}$-in. pipe serving bath and basin taps close together, it may be supposed that six separate draw-offs a day will represent an average house utilisation. This would cover use in the early morning equivalent to two separate draw-offs, a single one at lunch time (*i.e.*, several consecutive uses) and the equivalent of three separate draw-offs during the evening. The loss would then be $6 \times 290 = 1{,}740$ B.Th.Us. a day, or 3·6 kWh. a week, for the 10-ft. run.

In round figures, the pipe losses on a $\frac{3}{4}$-in. pipe for bathroom service will be about half those of a $\frac{1}{2}$-in. kitchen service with the same length of run. Moreover, the device for saving these losses will be the same as before, namely, an extra heater in the kitchen, the large heater being now moved close to the bathroom taps. The maximum economic length of bathroom piping may therefore be put at 30 ft. under the same cost conditions as before.

The table overleaf gives the results in round numbers for three sizes of iron pipe.

These calculations are based on the assumption of a rough surface pipe running horizontally in free air, indoors. Any restriction to free ventilation, due to running close to wall or ceiling or running vertically will

Loss in kWh.			
Due to :—	On 10 ft. length of pipe, bore :—		
	½″	¾″	1″
Single draw-off (falling to cold).	0·05	0·09	0·15
Per hour of use (fairly continuous)	0·15	0·18	0·21

reduce the loss, and of course burying in plaster will reduce it still more. Against this must be put the fact that the heat lost has been taken as though it was produced at 100 per cent. efficiency. On balance, the figures may therefore be taken as fairly representing average conditions for unlagged pipes.

In the case of lagged pipes the rate of heat loss will be one-quarter or one-fifth as great, and with continuous usage the losses will be reduced in this ratio. If allowed to fall to cold the loss will, of course, be the same as on an unlagged pipe, but the time taken to fall a given amount will be four or five times as great. Since in an unlagged pipe the water falls below utilisation temperature in about a quarter of an hour, in a lagged pipe it will do so in an hour. It follows that unless the pipe is used more than once an hour there is no object in lagging it.

These figures illustrate the advantage of using copper pipes wherever possible, an advantage which is now being recognised by electrical heating engineers. The chief advantage of copper pipes is that, being so much lighter, a given temperature drop entails less loss of heat, whilst the bright surface gives less radiation loss in a given time. Another advantage is that a copper pipe gives a considerably better flow than an iron pipe of the same bore, particularly if there are a number of bends. The extra first cost represents only a very small item in the total installation, and wherever there are frequent draw-offs the saving in losses will amply justify it.

CHAPTER IV

FIXING AND FITTING

THE foregoing chapter outlined the chief types of installations of complete water heaters to be met with, and the present chapter deals with the methods of carrying out the work. A subsequent chapter deals with immersion heater installations and the various combinations with fuel-firing.

Let it first be said that nothing is more to be deplored than some " electricians' " efforts at plumbing. Properly handled, the water-heating load may grow to become a very appreciable proportion of the total output of a station. But this will certainly not be obtained by the use of " gadgets," the main selling points of which are that " no fixing is required," the water connection consisting of a length of rubber hose to be fitted to the nearest tap. Business can only be built up on the basis of an installation that can be relied upon to give faultless service for a long period. Any reputable engineer will agree that it is essential to carry out first-class wiring work in order to obtain trouble-free results. Exactly the same principle should be applied to the plumbing work, with the aim not of providing some hot water easily, but of providing at a reasonable cost a permanent and ample hot-water supply.

Height. Regarding the height above the floor level at which the heater must be fixed, several points call for consideration. Firstly, with heaters having bottom baseplates with vertical elements and thermostat (so that the interior is withdrawn downwards), it is essential that sufficient clearance be allowed. Dismantling and

cleaning can then be carried out without unnecessary disconnection of pipework or removal of the heater from its position. The length of the interior gear varies with the manufacturer and should, therefore, be previously ascertained and kept for reference. (With heaters having horizontal elements, these notes do not apply.)

Secondly, with heaters fitted to discharge directly into the sink, bath or basin, splash must be reduced to a minimum, leaving, however, ample clearance for the convenient use of all domestic utensils. The usual clearance allowed from the end of the spout is 15 to 18 in. for sink or basin and 2 ft. 9 in. to 3 ft. for baths. These distances are reckoned from the spout end down to the inside bottom of the sink, basin, etc.

In the case of sink and basin heaters, it is usually preferable to mount them somewhat to the side rather than directly over, since less inconvenience is then caused by the bulk of the appliance. Also in the case of sink heaters this position allows the water to be delivered *either* over the draining board *or* into the sink (according to the position of the adjustable spout).

Bath heaters are usually fitted at the tap end, as the space above is never required during normal bathing operations. Also, if fitted at the other end, a stain is liable to arise due to the water continually flowing down the inclined end of the bath. This applies more particularly to displacement type heaters. Heaters serving distant taps (no discharge direct from heater) are invariably fitted as high as possible, as this is a great advantage in modern property, where floor space is usually at a premium.

Fixing. The position having been determined upon, fixing is the next consideration. Consider firstly the forces present in, say, a 12-gallon heater (filled) which will account for some 180 to 200 lb. weight. A quick survey will show the tendency of movement on the part

of the heater when fixed as shown in Fig. 19. The weight is divided between all four brackets, but at the top two fixing points there is a tendency to move forward as well, the lower supports acting as a fulcrum. It is necessary, therefore, to use greater care with the top fixings, so as to ensure that both forces are adequately provided for. In the case of all heaters which are installed with expansion pipes (iron), it is good practice to arrange this in such a way that although no strain is attached thereto under normal conditions, should for any reason the fixings fail, assistance would then be given by it.

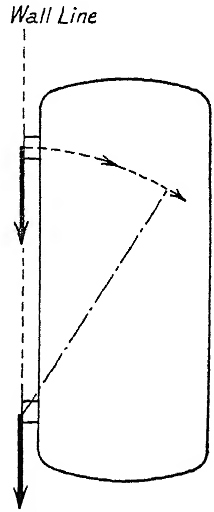


FIG. 19.—Forces on Heater.

The type and dimensions of the fixing projections can best be seen in the particular maker's list. Usually slots are provided for the fixing bolts. Some makers prefer holes to slots, although it is found that this increases the difficulty of fixing.

The two general forms of fixing are either with or without battens. The former, for all sizes up to 15-gallons capacity, consists of two wood battens, size $3 \times 1\frac{1}{4}$ in. planed (finished $2\frac{3}{4} \times 1\frac{1}{8}$ in.) and about 1 ft. 9 in. long, drilled as shown in Fig. 20. In each batten, $1\frac{1}{2} \times \frac{3}{8}$-in. coach bolts are recessed in from the back, as shown in section, nuts and washers completing the equipment. The fixing to the wall is by means of four $3\frac{1}{2}$ or 4-in. No. 12 steel wood screws and No. 12 Rawlplugs, where fixing to brickwork is required. For 20-gallon sizes, $4 \times 1\frac{1}{2}$-in. battens are suggested, with $\frac{1}{2}$-in. coach bolts and a suitably increased number of wood screws per batten.

The main advantage of this method is that, the battens

being taken to the job undrilled, almost any existing conditions can be met. For instance, on a substantial lath and plaster partition, the $\frac{1}{4}$-in. fixing holes can be drilled to suit the existing vertical studs. On a wall that is panelled or "lined" with matchwood or wallboard, the battens can be fixed directly to the wall, as shown in Fig. 21, neat slots being cut in the lining material.

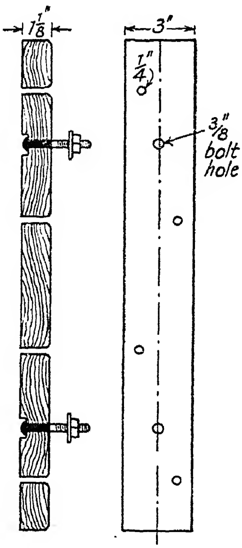


Fig. 20.—Battens.

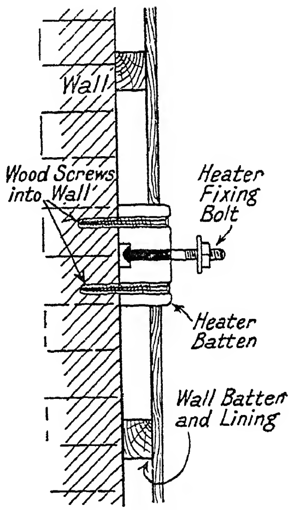


Fig. 21.—Battens on Lined Wall.

Another advantage is that the fixing bolts having metal threads with nuts, this provides for easy removal and replacement of the heater without fear of damage to the decorations.

The only objection to battens is that this type of mounting brings the apparatus $1\frac{1}{8}$ in. forward, which on some occasions is undesirable as it gives additional obstruction.

The alternative method of fixing, *i.e.*, without battens, is carried out with gimlet pointed coach screws, screwed direct into Rawlplugs inserted into the wall at the four

mounting points. With this method it is essential that the heater be held temporarily in its position while the fixing positions are accurately marked, after which drilling can be carried out. This method is, of course, restricted to brick-walls of hard and sound construction. The suggested sizes are :—

$1\frac{1}{2}$ to 5-gallon sizes :	$2\frac{1}{2} \times \frac{5}{16}$-inch screws,	No. 20 Rawlplugs.
12 ,, 17 ,, ,,	$3 \times \frac{3}{8}$,, ,,	No. 22 ,,
20 ,, ,,	$4\frac{1}{2} \times \frac{1}{2}$,, ,,	No. 26 ,,

Other alternatives have periodically to be considered

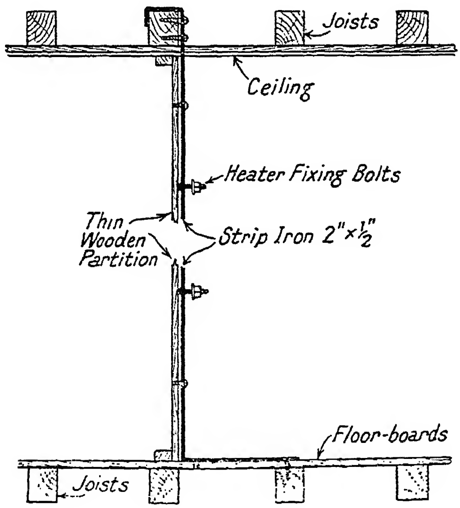


FIG. 22.—Iron Racks for fixing.

on account of special circumstances. These must generally be devised to meet the special case, but $2 \times \frac{1}{2}$ in. flat strip iron can be made into extremely useful racks with the tops turned to clamp to adjacent joists or screwed into position as at the lower end. Fig. 22 illustrates this.

Outlet Pipework. The following paragraphs refer to the fitting of new pipework for complete water heaters. A

note on the use of pipework from old installations will be found on p. 110. As regards outlet pipework there are two conflicting aspects to this, firstly rate of flow or volume required to be delivered in a prescribed period, and secondly, losses due to "dead" water. The latter term refers to water that remains in a non-circulating draw-off system when a tap is closed after water has been drawn. This water is fully heated at the time, but it quickly cools down and must be drawn off as cold water before further hot supplies can be obtained. It will be appreciated that this quantity of water is absolutely wasted, no useful purpose having been served by it whatever. "Lagging," or enshrouding the pipe with some poor conductor of heat, is of little use, except perhaps for a sink tap in very frequent service. Even then the tap will often not be used again until the water has become too cool for service. The chief aim, therefore, is to keep down pipe runs to the minimum limits both as regards length of pipe and diameter of bore, always keeping in mind, however, the necessity for allowing adequate amounts to be drawn without undue waste of time.

For sink supply in small domestic installations, $\frac{1}{2}$-in. bore pipe with a $\frac{1}{2}$-in. tap is ample, although this output can be appreciably increased by substituting a $\frac{3}{4}$-in. tap, this being easily accomplished by fitting a $\frac{3}{4} \times \frac{1}{2}$-in. elbow or socket, as required. The explanation is that a so-called $\frac{1}{2}$-in. tap usually has a smaller waterway. Consequently, when dealing with very low pressures, it is good practice to fit the next size larger tap than that which is designated with the size of the pipe in question. Sink draw-offs should not exceed 8 to 10 ft. if possible, the economic limit, under normal conditions, being about 15 ft. Above this, it would probably be more desirable to fit a separate heater to supply the sink in question. (This point is dealt with at the end of the previous chapter, under the heading of pipe losses.)

A more difficult aspect, however, is suggested by the following example. A bath and basin can be admirably served by a 12-gallon heater fixed above the former (not the ideal position, but the only one available). Hot water is required at the sink 30 ft. away, and a $1\frac{1}{2}$-gallon water heater is suggested in order to reduce losses. If there is no existing hot-water pipework that can be utilised, this may even reduce the plumbing cost, owing to the saving of the 30-ft. run. Moreover, provided the water authority is not averse, the heater can be connected to the main, a considerable selling point, since the main water is more useful for drinking and culinary purposes. A difficulty may arise, however, for maybe the washing is done at home, and large quantities (*e.g.*, 12 gallons) are required once weekly at the sink. It is then necessary to reconsider the whole facts again before being able to come to a decision that will enable the consumer to obtain the full service required with the minimum of initial and running costs.

For bath supplies, $\frac{3}{4}$-in. bore is recommended as standard. This gives adequate supplies, and owing to the fact that the basin taps ($\frac{1}{2}$ in.) are often connected to the bath supply, it is important that the pipe should not be enlarged unnecessarily, or considerable losses will occur when only the basin taps are used. For bath supplies, "dead" water has not to be reckoned with quite so seriously as the number of times it is likely to be wasted is smaller, hence 12 to 15 ft. is quite normal, while 35 to 40 ft. can be satisfactory, provided extensive use is not likely to be made of the bathroom basin. This is a matter which must be assessed beforehand, from the type and size of family concerned. In special cases, such as hotels, etc., 1-in. pipework is necessary, as baths are often required in extremely short periods.

Showers and Sprays. The following notes refer to the outlet piping for supplying showers and sprays as used

by hairdressers, etc., and occasionally in private houses. For the former purpose, the heater should be centrally placed and of liberal size, to supply ample storage capacity, the 12-gallon size being the minimum where spray attachments are used. This size is suitable for one to two basins, according to the class of trade, although the 15-gallon size is to be recommended for two- or three-basin

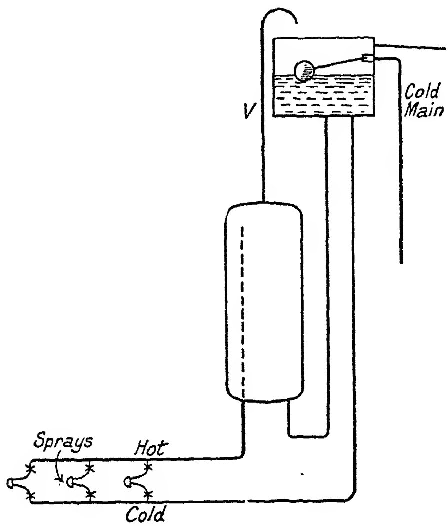


FIG. 23.—Supply to Sprays.

installations. By erring on the high side at the commencement, two advantages are obtained. Firstly, the water can be stored at a lower temperature, which reduces the risk of scalding, and secondly it allows for an easily increased capacity in the event of a greater demand at a later date, due to increased trade.

Regarding pressure, when mixer valves are employed for sprays, it is essential that great differences of pressure between the hot and cold supplies shall not exist. It will be noticed, moreover, that when several supplies are

taken from one pipe, there is always the tendency for the first tap to starve the last. When both are in use together, the latter especially shows rapidly varying temperatures owing to the alterations in the supply pressure and consequent change in the ratio of hot and cold water being supplied at the tap. This danger will obviously be increased if the hot and cold cisterns are running at different pressures, particularly when the cold supply is high, due to running off the main, and the hot supply low, as from a self-contained ball-valve heater fitted in the saloon.

It is recommended, therefore, that the main be never used for the cold supply, and the most satisfactory arrangement is when both supplies are fed from the same cistern, as shown in Fig. 23. It is also recommended that, whenever possible, 12 to 15 ft. head of water should be obtained to ensure adequate supplies. The hot storage would be supplied either from a semi-pressure heater, as indicated in the figure, or else from a tank or cylinder fitted with immersion heater and thermostat. The latter, of course, will show considerable saving in capital cost, especially for 20-gallons capacity and upwards. Moreover, it is often more simple to build such units into the space and position that is available.

Under conditions such as are encountered in this trade, the lagging of draw-off pipes is often useful, and adds to the general efficiency of the installation.

Inlet. Most water heater manufacturers design their heaters with outlets of larger dimensions than the inlet pipe, and one might receive the impression that these sizes should be continued in the pipework connected thereto. This, however, is incorrect. The reason for the increased size of outlets is that it is here that fur will subsequently manifest itself, and the larger bore is to permit a considerable formation to occur before any trouble (in the form of restricted water supply) becomes

apparent. With the exception of supplies from the main, the inlet pipe should always be at least as large, and for preference larger, than the largest outlet connection. Objections may be raised as to the object in bringing, say, a 1-in. inlet pipe to a heater which has only a $\frac{3}{4}$-in. outlet. However, in practice, especially when working with very low pressures, considerable benefit is obtained by this method, as a "speeding up" of the water takes place in the few inches of pipe at the heater, and the output is considerably in excess of what would have been obtainable if only a $\frac{3}{4}$-in. pipe had been provided for the whole length of the inlet.

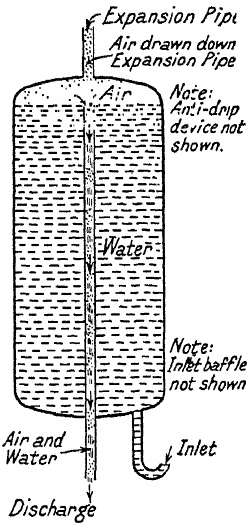


FIG. 24.—Restricted Supply.

At this point a somewhat curious trouble and its remedy should be noted. A pressure-type heater is fitted only a few feet below the cistern which supplies it, and discharging to a bath in close proximity. The heater, when turned on, runs at full bore for some 40 or 50 seconds and then begins to splutter, obviously discharging a mixture of water and air. Where does the air come from? The trouble will probably be traced to an insufficient supply at the inlet, either being fed by too small a pipe, or obstructed. This means that water is able to "get away" from the heater at greater speed than it can enter. Fig. 24 shows what actually happens. When the outlet tap is first opened, a good supply is obtained because the contents of the expansion pipe makes up the extra amount between the incoming and outgoing volumes. After some seconds, however, depending on

the length and size of the expansion pipe, this is drained and the only supply is that which is displaced by the incoming supply, the level having dropped to the top of the internal delivery tube. Consequently, only a small volume is discharged, with which is mixed a quantity of air which is obtained down the now empty expansion pipe, which may, quite possibly, air lock and cause further difficulty when refilling.

The above trouble only arises when pressure is poor, and is remedied by either increasing the size of the inlet pipe, restricting the outlet by fitting a smaller bore tap or fitting a non-return valve in the expansion pipe. The first method is the most desirable, and the third should only be used as a last resort, for although it does restrict the entry of air and produce a syphon effect, it is always undesirable to introduce any form of possible obstruction into the expansion pipe. Should this course be adopted, care must be taken to ensure that the valve is as far away from the heater as possible, so as to prevent any deposit of fur that might obstruct the pipe. Valves fitted at the extreme end of the vent pipe and above the water level are the most reliable, but the seatings must be gastight or air will leak through.

It has been stated already that wherever heaters are running off a low-pressure water system, it is preferable for them to have their own supply direct from the cistern. This particularly applies to bath heaters, since baths are required with a minimum of delay in running in the necessary water, both hot and cold. Such heaters should, if possible, and certainly where the pressure is low, be connected to a service other than that supplying cold water to the bath, to ensure that both taps may run at full bore simultaneously. These remarks depend on local conditions, the disadvantage of reduced flow being overlooked where installation costs must be kept at a minimum.

When it has been found necessary to take a supply from a pipe which is serving other taps or appliances at a lower level, a desirable precaution that may be taken is to arrange that the point of connection is above the top of the heater, *i.e.*, at " A," Fig. 25, and not as shown dotted (" B "). This considerably reduces the risk of the heater being inadvertently drained should the supply be withdrawn without notice. If fitted as shown dotted, it will be seen that the entire contents can be drawn off from either of the lower cold taps. It is true that hot water would be appearing from a cold tap, but if water is in demand and other taps are dry, it is likely that the contents will be drawn off and the heater completely drained with unfavourable results. These remarks do not apply as rigidly to displacement-type heaters, since in this case the tap on the inlet must first be left open, an improbable occurrence, since it would probably be closed again by sheer force of habit. In any case, it requires two taps to be opened simultaneously, a combination of circumstances unlikely to arise in practice.

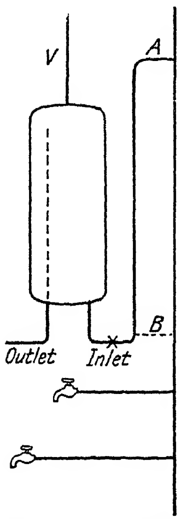


FIG. 25.—Point of Connection.

All semi-pressure heaters should be installed with a control valve in the inlet pipe, as shown at X, Fig. 25, to enable the supply to be shut down to effect renewals of tap washers or for inspection purposes. If when this valve is closed hot taps are subsequently opened, only the contents of the draw-off pipes will be discharged, the container remaining full of heated water, because the driving force from the cold tank has been withdrawn. This will provide for the easy re-washering of taps without draining the heater or interfering with the other services.

This valve should be of the gate pattern, full way, so that no retardation to the flow is incurred.

Expansion Pipe. As previously explained this pipe has two functions, *i.e.*, that of "venting" the system, or disposing of the air produced when water is heated, and also of assuring that under no circumstances can a pressure be built up, thus largely reducing the chances of accident. The expansion pipe can always be made part of the draw-off system whenever required, as reference to the various illustrations will show, but it is desirable that the pipe rises continuously over its entire run, or at least does not fall at any point. The reason for this is that air bubbles tend to collect at the highest point, and should there be a dip anywhere, they will congregate at this point until a large bubble is formed. Strange to say, this invariably arrests, or completely stops, the flow of water, giving what is termed "air lock." Where the expansion pipe is incorporated with the draw-off, the size of pipe is, of course, governed by the number and type of taps to be supplied. After the last tap has been fed, ½-in. pipe is quite suitable, since by this time it is at sufficient distance from the heater to make the formation of fur a negligible item. When no taps are supplied by the expansion pipe, ½ in. is sufficient throughout.

The expansion pipe must always be taken to a position above the level of the tank supplying the system, it being usual to allow 2 ft. above the water level or, say, 1 ft. for every 20 ft. of height between the tank and the point where heat is applied. This is necessary because the expansion of water from cold to boiling is about 4 per cent., so that a 24-ft. column of cold water will support a 25-ft. column of boiling water. The foregoing allowance is therefore somewhat more than that theoretically necessary, particularly as the expansion pipe is rarely kept at full temperature, but it is good practice to allow an ample margin.

The top of the expansion pipe is always turned over, care being taken that, should any discharge of hot water take place, it will always be in such a position that no trouble can be caused by splashing, etc. Usually the expansion pipe returns to over the tank that feeds it, but it can be terminated anywhere provided that the end is above the tank level and so arranged that any discharge will be made without danger of scalding.

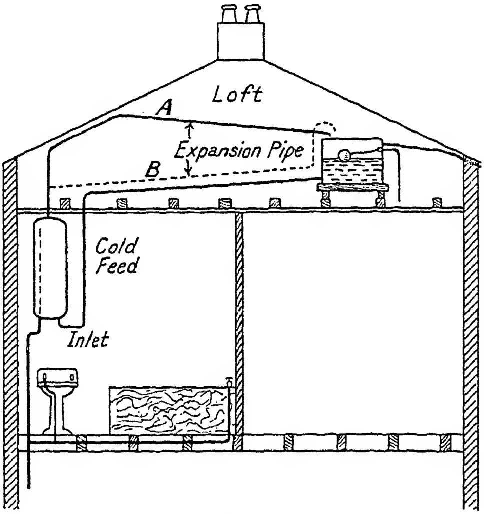


FIG. 26.—Expansion Pipe.

When a long expansion pipe is run across a loft (Fig. 26), it should be run as shown at A rather than in the dotted position B. This is an additional protective method against frost and radiation losses, since the majority of the pipe in the loft is then maintained high and dry.

Safety Valves. It is sometimes said, and may be found in some manufacturers' lists, that the expanded water can be disposed of by means of a pressure relief valve. This is definitely not recommended by the authors, and is, indeed, forbidden by practically every water authority

in the country. Relief valves, when fitted to installations which do not receive careful and regular overhaul and testing, may easily become choked with scale deposits and rust, and no reliance can be safely placed upon them. Furthermore, such a valve must of necessity be set at a pressure considerably above that of normal working, which renders the boiler liable to be called upon to withstand undue pressure with accompanying risk.

Cistern Fitting. There are a number of cases in which a cistern will have to be provided. There may not be a low-pressure supply adequate for serving the heater, or, if available, the present cistern may be so far off that it is impracticable to run an expansion pipe to it. The new cistern should be mounted as high as possible but with a minimum clearance of 9 to 12 in. between it and the ceiling, to allow for adjustments being made to the ball-valve. The position should be as centrally disposed as possible, having regard to the four sets of pipework involved, namely, inlet supply from main, cold feed to heater, expansion pipe from heater and overflow from cistern.

The size of the pipe from which water supply for the cistern is obtained does not greatly matter, as in any case the amount passed by a ball-valve is not excessive, being about one-third of what would pass through an ordinary tap at the same pressure. It follows that either main or low-pressure supply can be taken, whichever is more convenient.

Overflow Pipes. Overflow pipes from cisterns and cistern-type heaters should be at least one size larger than the main supplying the tank, and, in hard water districts, made of lead, as this will not corrode or rust and clog up. It must be remembered that the supply is usually under pressure, and that in the event of failure of the ball-valve, the overflow pipe has to dispose of the excess of water which is only under its own pressure due to gravity.

Overflow pipes are often looked upon as a more or less unnecessary fitment, but in the event of failure of the ball-valve they have an important duty to carry out.

Overflows should fall over their entire length, and should always terminate in a prominent outdoor position, and not so as to discharge into sinks or drains. Water authorities are insistent upon all overflow pipes acting as warning pipes, and they should, therefore, be so arranged that inconvenience will be caused by the discharge of water, to ensure prompt attention to the fault. This is also necessary for the consumer's own protection, as a faulty valve needs immediate attention, since it will rarely right itself.

Draining. Curiously enough, though obviously wrong, it is the habit of many fitters to construct and fill complete hot-water systems without making any provision whatever for draining, a requirement that is bound to arise at some subsequent date. Others, again, are satisfied with fitting a tee with plugged outlet, which is a particularly bad practice when the situation is such that any splashing or spray of water will damage fittings or decorations. Sludge cocks with loose keys, to prevent mischievous misuse, and hose unions to facilitate draining, are very reasonable in cost, and should always be fitted in a position as low in the system as possible.

Air Lock. The previous section has explained one way in which air lock can be caused in the pipes, but, unfortunately, the same result often occurs when a system is being refilled after having once been drained. Moreover, it is sometimes a serious and lengthy process to displace the offending bubble of air which has become trapped in the pipe. The following method, although somewhat troublesome, is nearly always certain. Moreover, this is a trouble which can better be met by force than by waiting and hoping.

Consider, for example, a water heater working in conjunction with a coke boiler. Air lock seldom occurs in the flow and return pipes from the boiler, as when filling down the return pipe all air can escape by means of the flow pipe. Let it be supposed that no water can be obtained from any of the hot taps. There is usually available, somewhere near to a hot-water tap, a cold tap served from the main. These must then be connected together by means of a rubber hose pipe, the "jumper" and washer having been previously removed from the hot tap in question. When the main is turned on by one man, who stays in attendance, the other can go round and assure himself that water is available at all the remaining hot taps of the installation, which, when tested and found to be running properly, are turned off. The course of the water will probably follow the new (water heater) expansion pipe, and when this overflows it should be checked by obstructing the end with the finger.

The next course for the water then is back through the heater, out through the inlet pipe into the hot-water tank, and finally out through the hot-water tank expansion pipe. Immediately this flows freely without air it proves that all these pipes are now once more free, but it is still possible for the cold-water supply pipe from the cold to the hot tank to be air locked. If now the second expansion pipe is also stopped up, the only outlet will be *viâ* this cold supply pipe, and the fact that water is entering the cold tank can readily be confirmed by the disturbance seen at the bottom of the tank and the rising water level in the same. Water will now be passing through the whole system in a reverse direction, and will ensure the expulsion of any air. The main may then be shut off and removed, and the whole system will again function perfectly, after the "jumper" has been replaced in the tap in question.

The same treatment can be applied to any system.

The procedure can easily be worked out by arranging that the entire system is thoroughly flushed from beginning to end. Where radiators are installed, upon refilling after draining, it will be necessary to open the small air cocks that are fitted at the top of each radiator, and allow these to remain open until water flows. This is also necessary periodically during normal running conditions, to relieve any accumulation of air.

Frost. In any installation, protection from frost must be carefully borne in mind. Exposed pipework should always be cased in and covered with sawdust, or heavily bound with hair felt or other suitable protective covering. External tanks should be similarly treated, a lid being provided to exclude dirt.

Electrical Connections. The system of permanent wiring will be as local regulations or preference may decide, but the method of terminating this and connecting to the actual heater terminals calls for some comment. It is necessary to supply some form of switching, to enable the consumer to disconnect the heater during holidays, etc. A plug point is not recommended for this purpose, as it allows other apparatus to be used from the same point, with the consequence that the heater plug is not replaced and the error is not noticed until hot water is no longer available. Some hours must then elapse before service can again be obtained. Also the plug (if 2-pin) allows small portable and unearthed appliances to be used in the bathroom. There is, further, the risk of contact with live pins and danger of electrocution, and, with a two-pin plug, the possibility of reversal of polarity on the thermostat. In view of the revised (10th) edition of the I.E.E. rules, a double-pole all-insulated switch, mounted so that it cannot be reached by a person in the bath, provides a suitable method of controlling the supply. This ensures that the point is

used for the heater only, since the permanent C.T.S. wiring is carried direct from the switch to the apparatus terminals.

One rather important point is that the position of the cable entry into the heater should be at the rear so that only the shortest possible length is required to reach the wall and switch. Nothing is more dangerous and unsightly than a long length of wire trailing around the heater, the danger being that should it be clutched during a slip by the bather, the ends may part from the heater terminals and come away "live." The "live" side should always be connected to the thermostat, so that in the unlikely event of an earth coming on to the element and not causing a burn-out, the thermostat will still operate and switch the heater off when the maximum setting is attained.

Earthing. No question can arise as to the necessity of earthing electric water heaters. Earthing is, of course, essential, and the only question is as to the method to be adopted.

One method is to rely upon the water connections, whether lead, iron or copper, to carry any electrical leakage, which will then eventually find its way to earth *viâ* the cold-water main. Another method is to connect the apparatus plate on the heater to the nearest cold main supply pipe by a 7/·036 braided earth wire. In both these cases, if a union-type stopcock is fitted where the pipe enters the house, this must be bridged across to maintain continuity should the tap be removed for repair. A third method is to take an earth wire direct from the apparatus plate to the cold-water main at some position near its entry into the premises and before it reaches the stopcock.

The first method has been objected to for several reasons. It is found sometimes that a water installation used as an earth has a considerable resistance. It has even been found that the main-water supply to the cistern has been taken up and over the top of the cistern,

terminating in a ball-valve just suspended over the water and not in any way metallically connected to the tank. However, it is a very simple matter to cut a hole in the tank and refit in a proper manner if this should be found to be the case. An excess of packing at this point or at other joints may also result in resistance being set up. In the case of displacement-type heaters, connected direct to the main with copper tube and brass compression type fittings or soldered lugs, additional earthing seems to be quite unnecessary. Whatever may be said against this system of earthing, moreover, it has the great advantage of permanence, and it can generally be considered satisfactory provided that a low resistance to earth can be assured in the first place.

The second method is the simplest way of ensuring the necessary safety, and may be considered as reasonably satisfactory. The third method often occasions greater difficulties than the wiring of the mains supply itself, 40- and 50-yard runs being quite usual if carried out in bathroom installation. It may be difficult to run on the surface with any degree of neatness, and the disturbance to the consumer's premises is a further objection.

An earthing method which is sometimes employed is to connect the apparatus to the conduit or lead sheathing of the house wiring. This method should never be used with water heaters, particularly in the case of conduit wiring, since the resistance of a number of such joints is likely to be neither low nor constant.

Finally, it is suggested that every heater should, upon completion of the installation, be tested for the resistance of its earth, however provided, at the same time as the insulation test is made. In no case should this exceed 1 ohm, the figure given for conduit resistances by the I.E.E. rules.[1]

[1] I.E.E. *Regulations for the Electrical Equipment of Buildings*, 10th Edition, 1934, Regulations 1001 to 1008.

CHAPTER V

HOT-WATER SYSTEMS

General Principles. This chapter is devoted to a discussion of the principles of hot-water systems, and a description of the chief types of existing (non-electric) installations. The next chapter deals with their adaptation to electrical working.

The operating principle of any hot-water system can be summed up in the words " hot water rises," and this will explain why circulation takes place and the process of heating is made continuous. Water, when cold, is a certain weight per unit volume, roughly $1\frac{1}{4}$ lb. per pint. If a pint of cold water is heated to boiling point and remeasured and weighed, it will be found that the volume has increased by about 4 per cent., but the weight will have remained the same, provided evaporation has been eliminated. A pint, therefore, no longer weighs 1 lb., but is lighter to the extent of the 4 per cent. increased volume, produced by the expansion due to heating.

Consider the same principle in a larger heated container. The water at the bottom immediately over the source of heat is warmed first and expands, becoming lighter per unit volume than the remaining cold water. The cold, or heavier, liquid tends to sink and the heated, or lighter, water is *forced* to the top. It is often assumed that hot water has the power to rise of itself, an incorrect though natural assumption. Actually, although the heating of the water allows the movement, it is the cold water that provides the actual " force." In this way, circulation is commenced, and it continues as long as heat continues to

be locally applied or until the entire fluid has attained its maximum temperature.

The water commences to circulate immediately heat is applied, and moves very quickly, but although fast-moving, there is no " power " behind it ; that is to say, the slightest obstruction will immediately stop circulation. This, of course, cannot occur in a simple vessel, but when the same thing is applied to pipes and appliances as later described, it will be found that the possibility of obstruction must be carefully watched. To summarise : water rises because the cold water, being heavier, forces it up ; the flow or circulation is speedy but lacks power to overcome any obstructions.

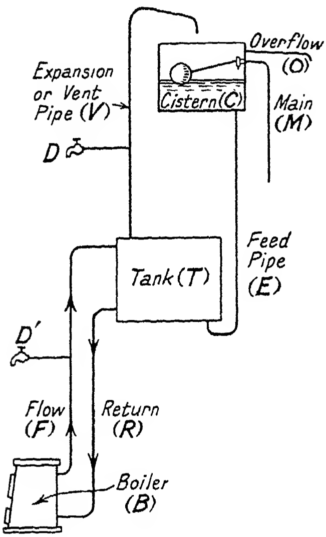


FIG. 27.—Hot-water System.

Fig. 27 gives a diagram of the several components and lay-out of a simple type of hot-water system. The component parts are all named and lettered, the same letters being utilised in subsequent drawings in this chapter. C is the cold-water storage cistern situated above all other parts of the system, and it must be of sufficient capacity to supply all normal requirements without being drained. This tank sometimes supplies low-pressure water to other cold taps, etc. The water main M is connected to a ball-valve, which maintains the level at some 3 or 4 inches below the overflow pipe, which is fitted to discharge outside the house. The water finds its way down the cold feed pipe E, filling the storage tank or

cylinder T, and the boiler B, together with the connecting pipes, also the vent pipe V up to the tank level. Heat is applied in the boiler, and is absorbed by the water, with consequent expansion.

Obviously, heated or lighter water cannot remain at the bottom of the system with the heavier water above, consequently the cold water commences to come down the lower pipe R, known as the "return," forcing the warmed water to rise up the higher pipe F, termed the "flow." This is known as the "primary circulation," and the two pipes concerned are called circulating pipes. The boiler cannot be more than a few gallons' capacity in most cases, consequently primary circulation is employed to convey the heated water from the position convenient for heating to the position suitable for storage and distribution. These pipes are generally 1 in. internal diameter or over, since with hard water scale may form at the boiler end.

Circulation pipes will be found always to rise steadily from the point where they leave the boiler until they terminate at the tank. This is in order to assist the circulation and to ensure that the air which is liberated whenever water is heated, can easily make its escape. Imprisoned air may produce an "air lock," and will in any case reduce the effective capacity of the boiler and tank.

Air is carried up the flow pipe to the hot storage tank and then to the expansion or vent pipe V. This pipe is taken to a point above the level of water in the cold supply tank, and usually over the same. Here it terminates with an open end, and consequently any accumulation of air can be freed. After heat has been applied to the boiler for some time, an amount of hot water is stored in the tank or cylinder in readiness for use.

In considering what happens to the heated water, take a typical installation, consisting of 25 gallons of water in

the cold cistern and 34 gallons in the hot storage tank, boiler and flow and return pipes. The water now having been heated and expanded 4 per cent., will have increased by approximately $1\frac{1}{2}$ gallons. Obviously, the capacity of the entire system can only be increased in the cold-water tank, and a rise of level in this will be noticed. The water will have entered the tank through the cold-feed pipe, the movement, however, being in the opposite direction from the normal. This point should be remembered in the adjustment of ball-valve type water heaters.

The taps or "draw-off" points can be connected in either of two ways, as shown at D and D′. The tap D, connected to the expansion pipe V, gets the hottest water available, and as the hot water is drawn off, cold water to replace it enters at the bottom of the storage tank. Consequently, the maximum volume of water at the maximum temperature is always available at this point. It is considered the best practice, therefore, to draw all hot water from the top of the storage tank or cylinder either by a separate connection to the tank or from the expansion pipe, whichever is most suitable to local conditions. The alternative draw-off position D′ is less good, for reasons which are explained below.

Tank or "High Storage" System. In older property, installations similar to Fig. 28 will often be found, particularly in houses comprising a number of floors. It will be noted that all the hot taps are taken off the flow pipe, whilst the storage tank is situated at or near the top of the building. This is frequently known as the tank system, since it is usually associated with a rectangular rather than a cylindrical storage tank. It is in fact necessitated by the pressure limitations of the rectangular-shaped tank. The thickness of the metal from which a hot tank is constructed, to a certain extent limits the internal pressure to which it may be safely subjected, but a good quality tank of $\frac{1}{8}$ in. thickness is

only tested for 10 ft. head of water, and is, therefore, totally unsuitable when fitted near the boiler subject to, say, a 50 to 80 ft. head. It should, however, be explained that the name " tank system " is applied to any system employing high storage, whether the hot tank is rectangular or cylindrical.

In this system, when taps are opened, the water from the tap is obtained from the flow pipe in two directions, *i.e.*, from tank and boiler. The same remarks apply to D′, in Fig. 27. When the fire has been lighted for only a short period, the water in the boiler and flow pipe is hot, and possibly an inch or so at the top of the tank, so that the supply at the tap is hot for the first minute but immediately afterwards runs cold. This may be advantageous for a sink tap, where small quantities of water are required quickly. When half the tank has been heated, the tap then gives the same hot water for a minute or so, this being due to the water coming from the flow pipe, tank and boiler, all of which are hot. As the boiler is emptied of heated water, it is replaced by cold from the lower half of the hot tank, which, coming down the return pipe, passes rapidly through the boiler without being heated. Ascending the flow pipe, it meets and mixes with the descending hot water on its way to the tap, with, of course, unsatisfactory results. The same trouble occurs even when the whole of the hot tank is heated, except that the hotter water remains available for a longer period.

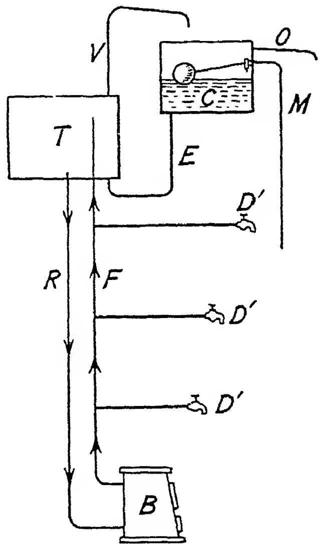


FIG. 28.—Tank System.

Even then cold water soon comes into the bottom of the hot storage tank and passes down the return pipe, and through the boiler, as before.

The only advantage of the tank system is that a small quantity of hot water can be obtained soon after the fire is lit, and that a quick service is obtained from all taps near to the flow pipe. The disadvantage is the water mixing whenever a large bath is drawn. This system will be found particularly difficult to convert to electric heating.

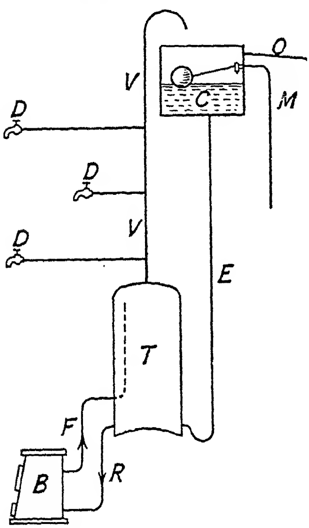


Fig. 29.—Cylinder System.

Cylinder or "Low Storage" System. In this case a cylindrical hot-water container is employed which, on account of its shape, is able to withstand, approximately, five times the pressure of a rectangular tank of the same gauge material. This allows the storage cylinder to be placed in a position near to the boiler, under a greater head of water than with the tank system.

In Fig. 29 it will be seen that the underlying principles are the same as before, but this time all draw-offs are taken from the expansion pipe, which is connected to the top of the cylinder, where, of course, the hottest water is available, while the flow and return pipes are considerably shortened. Moreover, a large proportion of the total hot water stored can be drawn off without cold admixture.

The main disadvantage with this system is that the farthest tap from the hot storage entails some period of

waiting after the tap is turned on before hot supply is obtained. Lagging the pipes would generally be of little value, since the bath and basin taps are not in continuous use.

Secondary Circulations. It will be clear from the foregoing that in any large fuel-fired installation it is inevitable that some of the taps will be situated a considerable distance from the heat storage. It is in order to counter this that "secondary" circulations are introduced. But since considerable pipe losses are thereby set up, it is essential, when conversions are in hand, that no secondary circulation is allowed to remain connected. In such cases, the electrical method is to divide the requirements into several smaller systems with separate "heating centres," so that the water is heated and delivered where required.

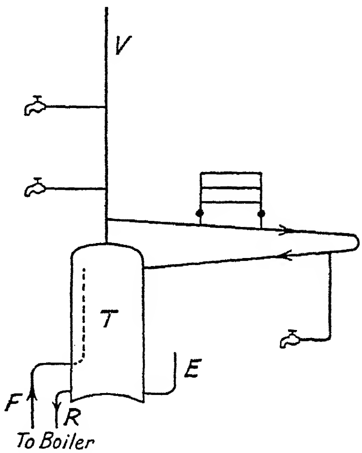


Fig. 30.—Secondary Circulation.

Reverting, it will be remembered that the pipes connecting the boiler to the storage tank or cylinder are called the flow and return, and constitute the primary circulation. Secondary circulations are on similar lines, and the same thermal principles cause the movement of the water. They are employed to transmit heat for a particular operation, as in the case of a towel rail or radiator, or else to enable hot water to be instantly drawn at any tap, reducing the amount of cold or dead water, as it is termed, to a minimum. Figs. 30 and 31 show two such examples.

In Fig. 30 the secondary circulation is supplying one

or more taps on one floor while others are fed direct from the expansion pipe. Fig. 31 shows all the draw-off points supplied by one secondary circulation. It should be noticed that to provide instant hot water at the taps, the entire length of the secondary has to be kept at the greatest temperature, with maximum heat losses. The return of the circulation is usually connected to the storage tank about 6 in. from the top. The apparently

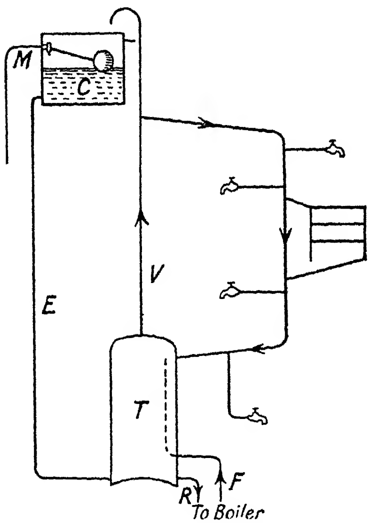


Fig. 31.—Secondary Circulation.

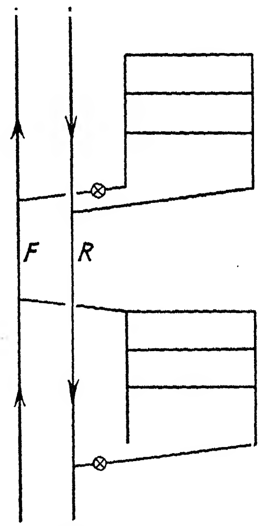


Fig. 32.—Heaters off Vertical Flow Pipes.

slow speed of movement of secondary circulation is not of such great importance as in a primary circulation where a large quantity of heat has to be transferred from one position to another ; but it is essential that, when a tap is opened, the water (which will be drawn from both directions) shall be at the maximum temperature. If the secondary was returned to the bottom of the storage container, the old trouble of a mixture of hot and cold water arriving at the tap would again develop.

Fig. 32 shows two small secondary circulations supplying a towel rail or airing cupboard heating coil, from a vertical primary circulation, while Fig. 33 shows the same arrangement taken from a horizontal primary. In these two cases, since these appliances are connected up below the hot storage tank, they will not interfere with the conversions to electric heating, as they will only be heated by the fired boiler.[1] In Fig. 34, however, the towel rail is supplied from above the tank, and in the case of immersion heater conversion, it would be necessary to intercept the circulation with a valve, to prevent radiation

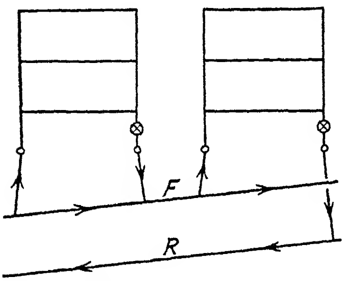


FIG. 33.—Heaters off Inclined Flow Pipes.

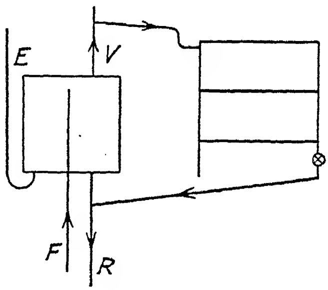


FIG. 34.—Heater off Expansion Pipe.

losses. Cases are also found where towel rails are connected up as part of a secondary circulation, supplying draw-off taps, and here again care must be exercised and all pipes traced out (see Figs. 30 and 31). Air warming or cupboard heating can usually be carried out by the direct method of tubular heaters or similar apparatus, more satisfactorily and economically than by electrically heated water.

Radiators : Indirect System. It is sometimes found in small modern installations that one or more hot-water radiators are run from the same coke boiler that provides

[1] It is assumed in all cases that the electric heating is applied at the storage tank.

the hot water, giving favourable results. This does not generally interfere with conversions, but great care must be taken that no pipe alterations are made which will interfere with the secondary circulation supplying the radiators, also that the electrically heated water will not circulate in these pipes when the fired boiler is not in use.

The most simple installations are of the direct-heated

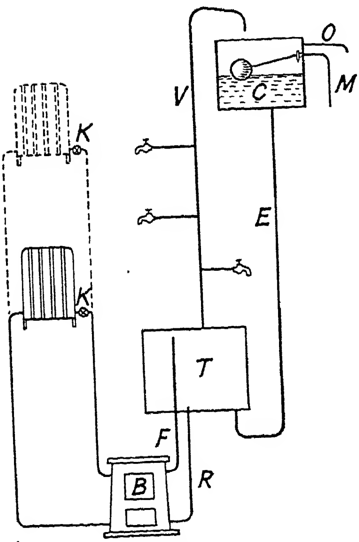


Fig. 35.–Radiators: Separate Circulation.

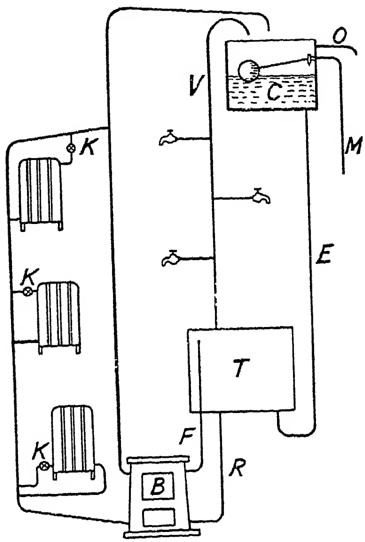


Fig. 36.—Radiators: Separate Circulation.

type, as shown in Figs. 35 and 36, a stop valve K being inserted to control the heating of the radiators. Since the radiator system forms a separate circuit, connected direct to the boiler only, it may be disregarded, and the conversion considered as for a standard system without radiators. The various arrangements shown in Figs. 30 to 34, and intended to represent small cupboard heaters and towel rails, can also be used for full sized radiators.

One disadvantage of direct radiators is that the water

which circulates through the radiators and which is liable to become flat and rust discoloured, also mixes with the domestic hot water, making it less suitable for culinary purposes. Another disadvantage is the scale formation. The alternative to this is the indirect system, as shown in Fig. 37. In this case the radiator pipes and the domestic water pipes form two distinct systems without any common water circulation. The radiators are connected directly to the boiler, and to the same place is connected a heating coil, or calorifier. This coil is in a tank and surrounded by the water serving the domestic supplies. Thus the radiators and calorifier coil are heated directly, whilst the domestic water is heated indirectly by conduction through the walls of the calorifier coil.

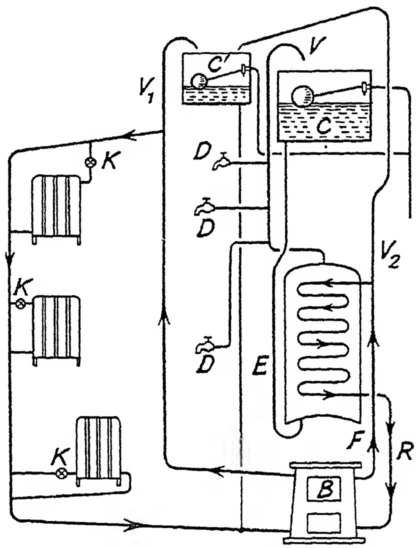


Fig. 37.—Indirect Heating (Calorifier).

It will be noted that the domestic supplies are fed from the usual cistern C, and are vented by the expansion pipe V. The boiler is fed from a small tank C′, which need only be of 2- or 3-gallons capacity, for making good any losses due to evaporation, etc., in the radiator system. The two circulations from the boiler are vented at their topmost points by the pipes V_1 and V_2.

The indirect calorifier system has considerable advantages when a number of radiators and domestic hot water are required, particularly in hard-water districts. There

is no water connection, and therefore no contamination of the one by the other. Furthermore, the only water that passes through the boiler is the comparatively small amount contained in the radiator system, which, once it is heated, is softened, and any further deposit or fur is thereafter eliminated. The disadvantage of the system, apart from the extra first cost and complication, is that the domestic hot water is not so quickly heated, since it has to be warmed by the immersed coil.

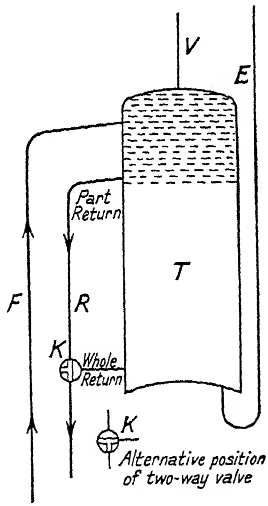


FIG. 38.—Variable Storage.

Other Connections. There are many special connections designed to perform particular functions or to suit local conditions, and mention of some may be of interest. It is sometimes found necessary to restrict the active capacity of a cylinder for reasons of economy. This method does not usually apply to a tank, owing to its shape, but the long vertical length of the cylinder makes it ideal for this purpose. The principle, however, applies in both cases. Fig. 38 shows an arrangement for reducing the active capacity at will, by the addition of a three-port two-way valve K which has the effect of returning the circulation at two different levels. When the valve K is closed, the shaded portion of the cylinder only is heated. A similar result can be achieved very simply on an electrical system by employing two heater elements at different heights.

The above must not be confused with the arrangement shown in Figs. 29 to 31, which is often met with in practice. In this case, the flow and return pipes, although

appearing to enter the tank at about the same level, operate as though they entered at top and bottom. The reason for this arrangement is that cylinders are often fitted in a confined space and it is impossible or unsuitable to bring the flow and return pipes through the adjoining brickwork except at the same hole. The flanges are, therefore, fitted close together, the extension, as shown dotted, being made by a "standpipe," fitted inside the heater, this being brought up to within 2 or 3 in. of the top.

There is no objection to two or more sets of flow and return pipes being connected to one tank or cylinder, these being connected to different heating units, a practice usually adopted when gas circulators are fitted.

In circulating systems, "gate" or other types of "full bore" valves are invariably used to control the circulation, as they provide a clear passage which does not offer resistance to the passage of water. The under-and-over type screw-down valves offer a considerable impedance in this respect, and are liable to air lock. Gate valves, however, may not be perfectly watertight when tested under pressure, especially after a considerable period of use, as metal-to-metal seatings are liable to corrode and no apparent remedy is available. This is, however, of little importance.

Gas-heated Systems. Finally a few descriptions of gas-heated systems will be given. The gas geyser, which supplies heated water to the one point only, is usually connected to either low-pressure or main supply, according to the local water authority's regulations. Multipoint gas geysers, to which the entire hot-water installation of the house can be connected, are so arranged that when any hot tap is opened, the resultant flow of water operates the gas supply. The water, heated instantaneously, as in the case of a geyser, is then supplied to any tap where it is required. The pipework in this case is purely a

"draw-off" system, without primary or secondary circulations, and the difficulty of waiting for the hot supply, while the "dead" water is drawn off, may be considerable.

Circulating gas boilers, on a somewhat similar principle to the independent coke boiler, were at one time popular, in which the water is heated and transferred to the hot storage tank by a primary circulation in the usual way.

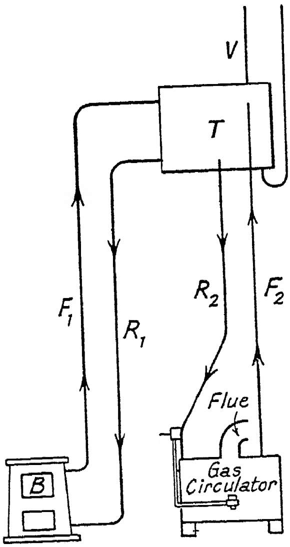


FIG. 39.—Gas Heater.

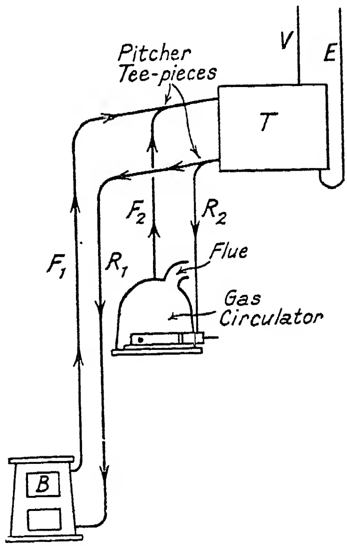


FIG. 40.—Gas Heater.

Either a new and separate flow and return will be found, as shown in Fig. 39, or, alternatively, the heater may be connected into the existing primary as shown in Fig. 40, using for this purpose what are known as "pitcher tee-pieces." These boilers are also made up with a hot-water cylinder mounted immediately above, having short primary connections, the whole forming a more or less self-contained unit. A two-way control valve is sometimes installed so that the hot water may be drawn at

the tap immediately after lighting, and before the storage tank is heated. A form of thermostatic control is usually arranged which reduces gas consumption when the water is completely heated.

Another type of heater dispenses with any additional pipework, being connected into the flow pipe as shown in Fig. 41. In this case the gas boiler is a bye-pass to the existing flow pipe, and its action is self-explanatory.

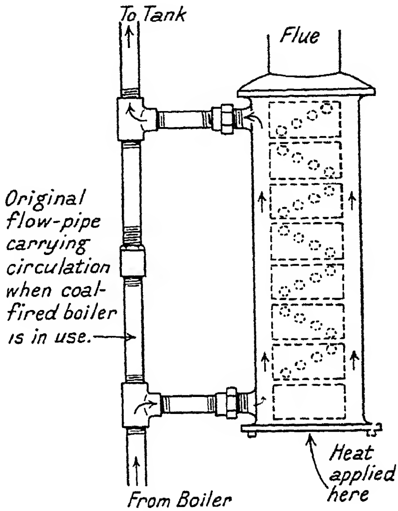


FIG. 41.—Gas Heater.

Later developments are types of gas storage heaters which are, to some extent, imitations of the electrical storage water heaters. As the water connections are similar to the pressure type of electrical heater, no further descriptions need be given, and no alterations are generally required to effect conversion.

CHAPTER VI

COMBINATIONS AND CONVERSIONS: IMMERSION HEATER INSTALLATIONS

Using Old Pipework. A case which sometimes arises is where the existing hot-water system is entirely obsolete and useless and is required to be discontinued, but the same hot points are to be supplied as before. The old boiler, it is presumed, is to be left out of use, so it is quite easy for the flow and return pipes to the boiler (from the kitchener, boiler back grate, etc.) to be cut and the ends *not* connected to the boiler capped off. This means that inevitably the boiler is left full of water. Under no circumstances whatever must these pipes leading to the boiler be left in any other condition than with open ends, a slow fire being lighted meanwhile. In a short period, maybe a few hours, the entire contents will have been boiled away, and it is then quite permissible for the fire to be used, as before, for room heating only. The boiler, now dry, will not give any further trouble, and will probably last for years.

The old pipework, now disconnected, will be at one's disposal, and it is highly probable that the entire distribution system (not the flow and return, however) will be in serviceable condition for connecting up to the new system. The flow and return may have become restricted through scale, but fortunately these are not required in the conversion. The condition of the interior of the remaining pipework, and the results that can be expected under the new conditions, can be determined by making a preliminary test before dismantling is commenced.

The feed from the cold tank to the hot is nearly always

separate, and this can be converted to serve as the supply to the water heater. Likewise, the draw-off pipework can be utilised. The expansion pipe can be reconnected in at some suitable point, but on no account must any secondary circulation, such as towel rails, cupboard heaters or radiators, be left connected. It is quite true that they can be made to work, but this is definitely uneconomical, and it also reduces the effective capacity of the water heater.

Combined Systems (sometimes called "mixed" or "in conjunction" systems). Any of the water heaters [1] whose construction, operation and installation have formed the subject of the earlier chapters can be operated in conjunction with a fuel-fired hot-water system. This means that the electric water heater inlet will be connected to a source of supply of already heated water, instead, as in previous cases, to a cold supply. No difficulty arises as to the pressure of this supply, since all such installations in this country are worked on the low-pressure system, *i.e.*, fed from a cold-water cistern. It will, however, be necessary to run an expansion pipe from the heater (unless of the displacement type) to a position above this cistern.

Fig. 42 shows a pressure-type electric heater connected to an "independent" coke-fired hot-water system. The heater is mounted in the kitchen rather than in the bathroom, so as to be near the most frequently used tap. A hot supply from the old system (*e*, *x*, *f*) is led in at the *bottom* of the new heater. This cannot therefore serve as an expansion pipe, and the heater must be vented at the top by a new pipe. A tee connection from this (at *c*) supplies the whole of the existing hot taps. But in order to shorten the run to the sink, a new pipe, *ab*, has been fitted in place of the old length, *db*. Moreover, since the

[1] There would, of course, be no point in using a cistern-type heater in this capacity.

pipe *ef* will be in very frequent use (though only at the fuel-heated temperatures), there will be some gain in lagging it.

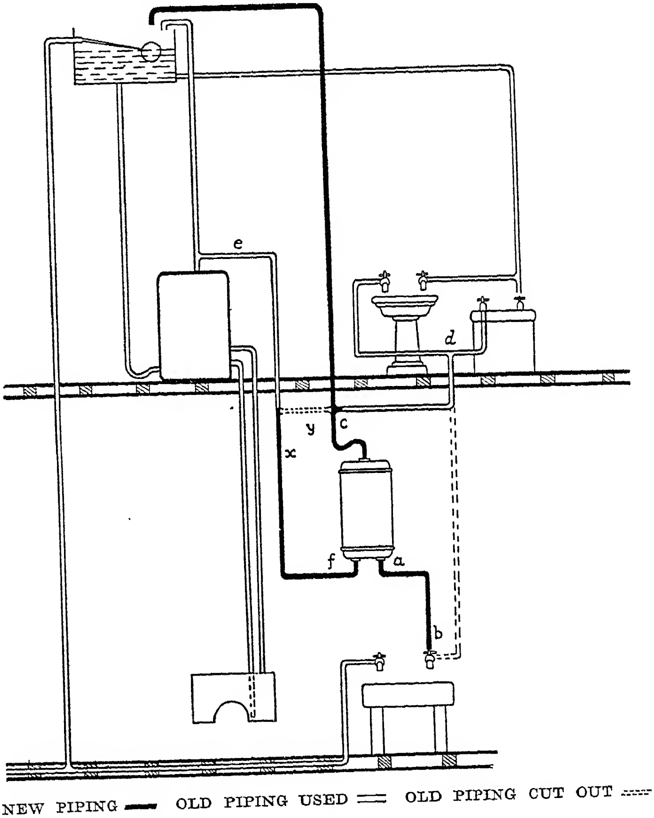


FIG. 42.—Combined System.

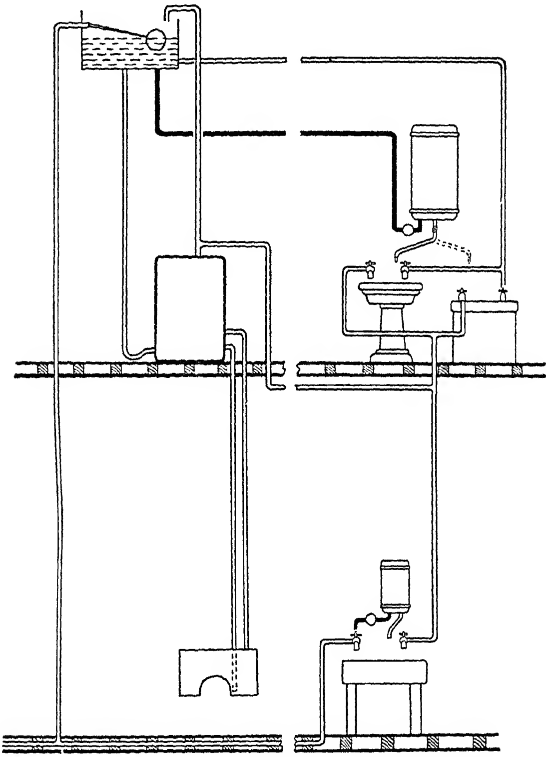
It will be found that there are a number of possible variations of the above arrangement. All that is necessary is to arrange that the water supply is obtained from the heated source, and that all taps that are required to be served with electrically-heated water are connected *direct*

to the electric heater. There is, of course, no objection to some of the taps being left still connected to the existing system, if desired. They will then be served by the fuel-heated water only. It is preferable that the supply to the water heater should be obtained from the top of the hot tank or a pipe connected thereto, as shown in the figure. There is, however, no great objection to the supply being obtained from the flow pipe should a more convenient connection be available, as is often the case when a heater is fitted near a sink and required to supply all taps. The existing sink tap supply can then be connected to the inlet of the heater, a new draw-off pipe being run to the sink. The existing pipework connected to the remaining taps is then connected to the top of the heater. The old expansion pipe can be utilised for the water heater and a new expansion pipe fitted to the existing hot-water system. It will be seen that two expansion pipes are necessary, as if one common expansion pipe were used for both systems, circulation between the water heater and hot-water tank would commence.

There is no reason whatever why a heater should not be connected to work in conjunction with a system having radiators, as described in the previous chapter. It is essential, however, before any alterations are carried out, that the entire radiator system is traced throughout, and that arrangements are made whereby the circulations of these radiators are not interfered with in any way. Where the radiators are connected to a separate circuit direct from the boiler, as in Figs. 35 and 36, no difficulties are likely to arise. Systems such as those shown in Figs. 30 to 33, where radiators, towel rails, etc., are in the main circuit, will require detailed consideration, as indiscriminate alterations to the draw-off and expansion pipe may easily affect the circulation of the radiator. Suitable reconnection must be worked out for each individual job. Heaters should in any case not be connected to obtain

supply from radiator
drawing is likely to di
quent discolouration of water.

Combined System with Displacement Heaters. As in



NEW PIPING ▬ OLD PIPING USED ═ OLD PIPING CUT OUT ┅

Fig. 43.—Combined System with separate Heaters.

previous installations, the question of pipe losses must be carefully watched. If the length *ab* (Fig. 42) exceeds 15 ft., or the length *cd* exceeds 30 ft., some better mounting position should be sought, and the advantages of two

separate heaters should be canvassed. The heaters could in this case be of the displacement type, thus dispensing with expansion pipes.

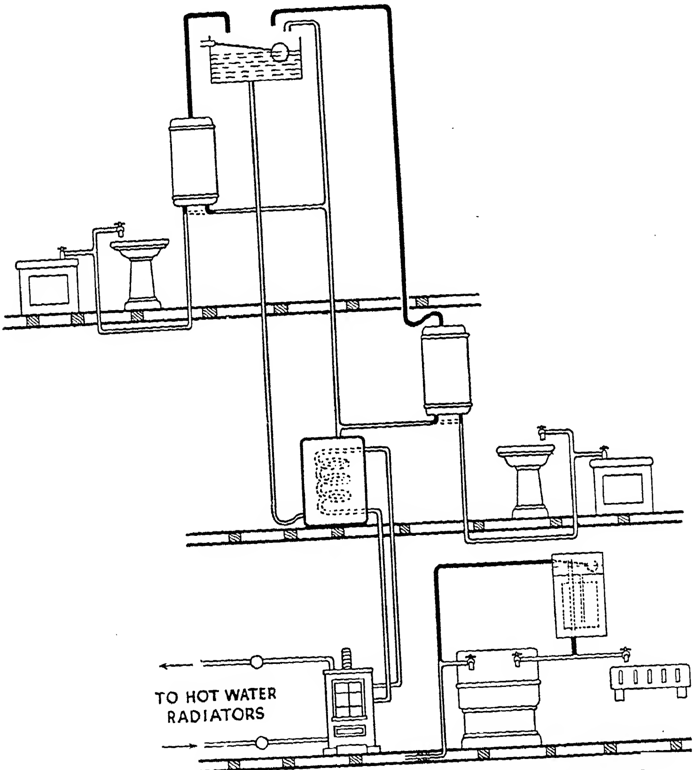
Fig. 43 shows the lay-out of an installation comprising two displacement heaters side by side with a fuel-fired boiler system. This is drawn on the same lines as the previous figures, with which it should be carefully compared. In the case shown, the electric heaters are entirely independent of the fuel firing, but as an alternative either or both could have been run off the hot pipe, as in Fig. 42.

Combination with Indirect Heating. Electrical water heaters can be similarly used in conjunction with the indirect heating (calorifier) system shown in Fig. 37. In this case the remarks already made about not drawing the water off from the radiator side of the system apply with particular force. Under no circumstances must the hot supply be obtained from the radiator or calorifier coil circuits, as this water is in continual circulation and is never changed. Consequently the contents will be particularly stale and discoloured, and wholly unsuitable for any use except as a heating medium. Moreover, the supply cistern is generally only of a few gallons capacity, and cannot give the large supply required for domestic purposes.

Since the indirect heating system is chiefly used in fairly large houses, there will often be long runs to the various hot taps. In such cases it may be more economical to install two or more heaters near to the points of utilisation. Fig. 44 shows an installation employing two pressure-type heaters, fed from different points of the existing hot-water system, and a cistern-type heater running off the cold main and supplying points on a lower floor.

Uses of Combined System. Systems such as those just described have a number of advantages. They enable

the householder to "ring the changes" between two sorts of heating, using either the electric heater by itself or both together as desired. When operated together, the one heating (electric) makes up the defects in the other,



NEW PIPING — OLD PIPING USED ═ OLD PIPING CUT OUT ::::

FIG. 44.—Combined System with Calorifier.

whilst the other reduces the cost of the one. This is because the electric heater, being thermostatically controlled, will automatically fill up any gaps left by the fuel heater, and will deliver the water at all times at a uniformly high temperature.

Another advantage of combined operation is that considerable additional storage is obtained. The electric heater stores sufficient for (say) one bath, but the hot tank also stores a considerable quantity of water at a rather lower temperature. As soon as a bathful is drawn from the heater its place is taken by warm or hot water from the tank. This will be heated up to the full utilisation temperature in a comparatively short time, and in the meantime additional warm water is being stored in the tank.

In the summer, or at any time when desired, the fire can be let out, and electricity will then take over the entire work of maintaining the hot-water supply without attention and without any change in the installation. If, on the other hand, it is desired at any time to operate the fuel-fired system by itself, this is not quite so simple. It can, however, be done by leaving in the dotted portion y (Fig. 42) and fitting valves at x and y. By closing x and opening y, it is possible to cut out the electric heater from the water system entirely. It should, of course, also be switched off, in order to save its own losses. In order to serve the kitchen sink, the run $d\,b$ can be left in with the original tap, and a new tap fitted off the electric heater.

Immersion Heater Installations: General Considerations. The term "immersion heater," in this connection, is used by contractors, and throughout the present book, to denote the building up of an electric water-heating installation using for this purpose the storage tank or cylinder of an existing hot-water system. It therefore involves the fitting of this tank with an immersion heater element, a thermostat and suitable lagging. It will also frequently involve the making a number of changes to the existing pipework in order to cut out extraneous circulations. The various details of such installations are dealt with in subsequent sections.

The chief advantage, of course, is a considerable reduction in capital costs, particularly on the larger sizes (over 20 gallons). This is because the component parts, including element, thermostat and lagging, can be bought for about £7, as against £20 or more for the larger sizes of self-contained boiler. It is true that the tank has to be drilled and fitted with this gear, but on the other hand there may be little or no pipework to be done, so that the total installation costs (apart from materials) may be as little or less than with self-contained boilers. The difficulty of finding space for the water heater is also got over, the builder having already provided for the original hot tank, though not always with sufficient clearance for the addition of lagging.

The chief disadvantage is that it is usually impossible to insulate the tank so effectively, and heat losses are therefore greater from the tank, and sometimes also from the piping, owing to its greater length. This may be countered to some extent by a lower thermostat setting, and it was seen on p. 67 that there is slightly less loss (other things being equal) from a large quantity of water at a lower temperature than from a smaller bulk at a higher setting. Also this plan gives the possibility of increasing the storage either temporarily or at some future date by the simple expedient of raising the temperature setting. The pipe losses will also be less at a lower working temperature. But if carried too far, a low setting reduces the value of the service, since kitchen water, at any rate, should be delivered at not less than 140° F. Moreover, although it is true that a storage tank or cylinder commonly has a bigger capacity than an electric boiler, the fact remains that one cannot have it both ways; with a given cubical contents a lower temperature setting inevitably means a smaller effective storage capacity. On the other hand, the tank capacity may be *more* than that required for electrical operation,

even with the lowest serviceable temperature setting. The losses will then be greater than those of a factory-made heater giving the required service.

Summing up the position, the immersion heater has the smaller first cost but may have a bigger running cost, and it is more dependent on the skill of the fitter for its efficient performance. The correct choice, therefore, depends partly upon the relative costs of capital and energy, and the following table has been drawn up to illustrate this point :—

	Complete Boiler.	Immersion Heater.
Capacity	20 gallons	30 gallons
Temperature setting	183° F.	140° F.
Effective capacity (diluted to 104° F.)	52 gallons	52 gallons
Quarterly hire charge	10/6	5/-
Tank and pipe losses per week	20 kWh.	28 kWh.[1]
Quarterly cost of losses (at $\frac{5}{8}d.$)	13/6	19/-
Quarterly cost of heater + losses	24/-	24/-

Assuming that it is impracticable to have a higher setting than 180° F. to 190° F., for reasons of furring, nor a lower one than 140° F., for reasons of utility, two hypothetical installations have been shown, working at these extremes. The two have the same effective storage capacity and give, as nearly as possible, the same service, namely two baths in succession. In the present case, the relevant costs total just the same for both, but it is easy to see that had the supply price been $\frac{3}{4}d.$, the boiler would have been the cheaper, and if $\frac{1}{2}d.$, the other would. In general, the bought heater is likely to be the cheaper proposition (overall), with energy at from $\frac{3}{4}d.$ or over, but with energy from $\frac{1}{2}d.$ downwards, there would appear to be an enormous field for immersion heater installations.[1]

The reason why the immersion heater is less satisfac-

[1] These figures are conservative and may easily be improved upon with good lagging and short pipe runs.

tory as regards pipework and requires more care in its installation is as follows. The self-contained boiler can be installed in any position suitable by reason of space or pipe run, whereas the immersion heater can only be installed in the hot-water tank which, if already in a bad position as regards pipe losses, will be still worse off when electrified, owing to the greater working temperature and the higher cost of the heat units. It is for this reason that the immersion heater finds favour in modern installations where pipe runs are comparatively short, and where the cylinder, after conversion and lagging, can be made almost as efficient as the self-contained heater.

Since the immersion heater is essentially an addition to an existing hot-water system, it can be used equally well on its own or in conjunction with fuel-firing. In the latter case it will automatically "top up" the heat level and supply any deficiencies left by the other system. It has, moreover, one advantage over the combined systems described earlier in the chapter, since they cannot be operated on fuel-firing alone, except by the provision of additional piping and the manipulation of sundry taps. With the immersion heater, the householder can use electricity only, electricity and fire boiler together, or fire boiler only. All that is necessary is to let the fire out or switch the heater off, as the case may be. The latter advantage lets him feel that he is not bound to use electricity during the winter unless he wants to, and incidentally makes him realise how much more effective is the thermostatically-controlled electric service.

Occasionally, hand control may be utilised instead of thermostatic, and under these circumstances, where intermittent "heat and use" is intended, the lagging is sometimes omitted. Such an arrangement is analogous to the unlagged heater described on p. 64.

Besides being employed, in the way described, as an adjunct to a fuel-fired system, the immersion heater can

be put in where no system at present exists. It then forms a means whereby the supply undertaking or the contractor may build up a complete boiler more cheaply, even if less efficiently, than they can buy one. Moreover, the plan is more flexible in the matter of dimensions, since tanks may be bought either rectangular or cylindrical, and in a variety of proportions. In fact, the immersion heater is sometimes the only solution to the problem of hot-water supply in small flats and houses where space is very limited. In such cases the installation of a square or oblong hot-water tank in some convenient position, together with immersion heater and thermostat, gets over the difficulty. The tank can then be lagged *in situ*, and when completed forms a very compact unit. Such places as cupboards and under kitchen draining boards have been successfully utilised for this purpose.

Tank Inspection and Renewal. Upon receipt of the first inquiry, it is essential that a complete inspection of the system should be made, with the object of determining the following two points : (1) the condition of the existing hot-water tank or cylinder, and (2) whether any secondary circulations exist, and also if any taps obtain their supply of hot water from the flow (or return) pipes.

As regards size of tank, 20 gallons is usually the smallest to be found, and this is sufficient provided two baths are not required in succession. It is, however, preferable to have a capacity of 25 gallons, while for two baths in succession a 30- or 40-gallon would be deemed advisable, according to the size and habits of the household. It will be seen from the table on p. 66 that in order to obtain the equivalent of a 20-gallon boiler at 180° F., an immersion heater tank set at 140° F. would require to have a capacity of 29 gallons, or, say, 30 gallons, allowing for the space taken up by the element and thermostat.

When inspection is made for condition, it should be

clearly explained to the consumer that it is impossible to give a satisfactory report upon its condition when only the outside is available to view. Most galvanised iron tanks appear practically new externally even after years of use. The only external indication will be in the nature of rust spots, these generally starting as white spots, somewhat like mildew, appearing on the underside of the tank. Should any be visible this is absolute proof that the tank is rapidly nearing the end of its useful life, and the consumer should be informed that, whether heaters are fitted or not, the tank should be changed at once to avoid leakage and probable damage to decorations. In no circumstances should these spots be touched in any way, not even by a careful wipe of the finger, as the smallest pressure may easily cause leakage to commence.

A leak on the tank during, say, the first three years would doubtless be attributed to " bad workmanship " on the part of the installation engineer. It is far more advisable, therefore, to take the long view, *i.e.*, to refuse to carry out installations upon tanks which do not appear good for at least five years' wear. Considerably increased labour would be required to change the tank after the apparatus had been fitted and the tank lagged. Should it appear, upon external inspection, that there is a possibility of the tank proving faulty when opened up for installation, the cost of a new tank and its fixing should be attached to every estimate.

In galvanised iron, the lightest tank listed is usually sixteen gauge, and this is practically useless, as its ordinary life is only about five or six years. Fourteen gauge is the next, with a life of approximately seven to ten years; consequently if it has been fitted fairly recently, it may be quite suitable. Twelve gauge is a size not so often met in practice, the better quality, $\frac{1}{8}$-in. plate, being fairly generally used. This has an average life of approximately twelve to sixteen years, and can consequently be

trusted even if it has given some years of previous service. This is, of course, subject to the internal inspection not disclosing serious accumulations of rust or corrosive deposits, these being particularly noticeable around all parts where pipes enter the tank and upon the lower side.

Should tank renewal be necessary it is not advisable to replace with anything lighter than $\frac{1}{8}$-in. plate, while if still greater protection is required $\frac{3}{16}$-in. plate can be obtained quite easily and is essential where subject to considerable head of water. It will also be found that in order to obtain the required thickness of lagging all round, in very many cases it will be desirable to have the tank made to special measurements. This can generally be done at small extra cost and with little delay. The tank manufacturer can also drill all holes required for the immersion heater, piping, etc., before the tank is galvanised, a great advantage if the holes are fairly large. Since the galvanising is then applied to the cut edges, this affords additional protection against rust forming at these positions.

Tank Conversion—Position of Elements. Having established the satisfactory condition of the hot-water tank or cylinder the next step is to convert it for electrical operation. This involves drilling and fitting it with heater element and thermostat. Subsequently it has to be lagged as described in a later section.

The actual elements and thermostats employed are exactly the same as those used in the self-contained boiler, and described in an earlier chapter. Usually they will operate equally well in a horizontal or a vertical position, but if there is any doubt the makers must be consulted on this point. Special care must be taken with vertical elements, unless these are of the flat-bladed or the cement-filled type. The removable core type, unless specially constructed for vertical as well as hori-

zontal use, are liable to give trouble by the spirals sagging and short-circuiting adjacent turns. No mention has been made of the size of the heating element, but unless there is any special reason for departing therefrom, the

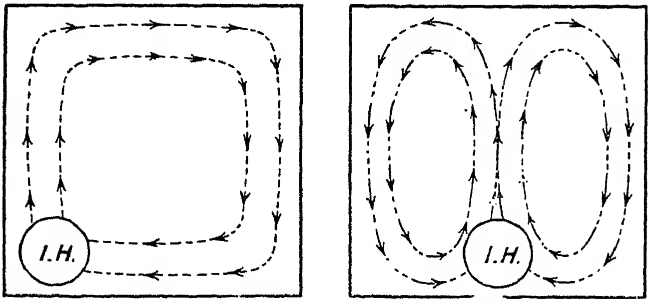


FIG. 45.—Circulation with Horizontal Elements.

ratings given in the particulars for complete boilers may be adhered to, namely, 2 kW. for 20-gallon, 2·5 kW. for 30-gallon, and 3·0 kW. for 40- to 60-gallon.

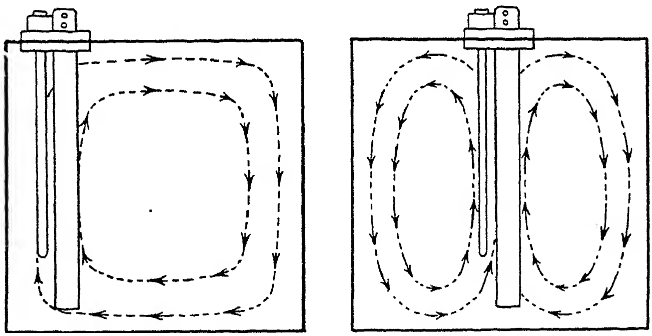


FIG. 46.—Circulation with Vertical Elements.

The most convenient arrangement from the fitting point of view is for the element and thermostat to be mounted parallel to each other and about 3 in. apart so that both can be attached to one apparatus plate. If they are too close there may be erratic operation of the

thermostat. Fig. 53, on a later page, shows a typical assembly of this kind.

As regards the position in the tank there is a considerable range of choice. Figs. 45 and 46 show four possible positions, and it will be seen that owing to the free movement of convection currents the whole contents of the tank are in each case circulated round into contact with the element. It will be noted, however, that no heating takes place below the heating element except for a very small amount of mixing and conduction downwards

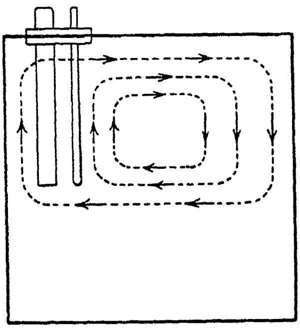


FIG. 47.—Circulation with Short Vertical Element.

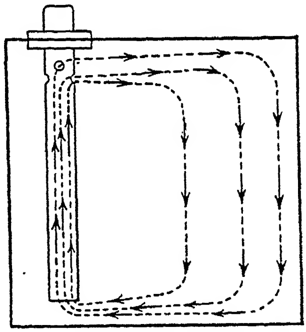


FIG. 48.—Circulation with "Circulator" (Element and Thermostat enclosed in tube).

in the water and tank sides. It follows from this, that if horizontal the element should be only a few inches from the bottom, and if vertical it should extend practically the full depth of the tank.

The above proviso introduces some difficulty in the case of vertical elements owing to the varying depths of the tanks. Fig. 47 shows that with an element which is half the tank depth and fitted from the top, only about half the tank capacity is brought into circulation.

This difficulty of thermostat and immersion heater length can be overcome however by arranging that they are both enclosed in a tube (Fig. 48), forming the now

popular " circulator " units. The primary object of the circulator tube is that of providing a small quantity of hot water in a minimum period instead of heating the entire contents slowly. Moreover, as various lengths of tube can be cut to fit any tank, it has the effect that the cold water from the base of the tank will be brought into circulation. Furthermore, the thermostat will not cut off until the stream passing through the tube, which represents the temperature of the entire contents of the tank, has reached the desired figure.

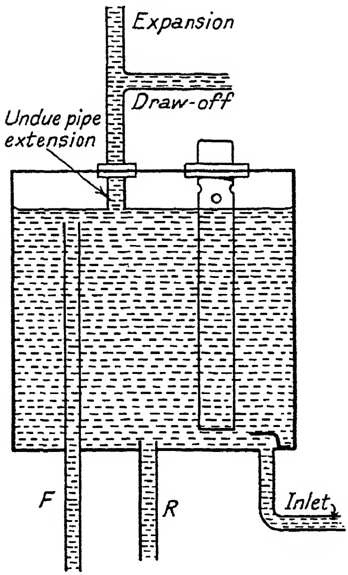


Fig. 49.—Air Lock due to Pipe Extension.

When fitting circulators, care must be taken to see that the existing pipework is not such that an air pocket is formed in the top of the tank as shown in Fig. 49, as in this case no circulation will take place, the thermostat cutting off immediately the contents of the tube are heated. The remedy is to remove the protrusion of tube inside the tank or to lower the holes in the circulator tube. The latter must be done only after it has been ascertained that the element will still be totally immersed.

In the case of horizontal fitting, since the whole of the element lies in the coolest water in the tank, a somewhat higher specific loading (watts per sq. in.) is permissible than with a vertical fitting. Furthermore, with the latter there is a distinct tendency to overheat at the upper end. This may be overcome by using an element

with graded loading, *i.e.*, having a greater loading density at the bottom than at the top (see Fig. 50).

By means of two immersion heaters installed horizontally at different levels in the tank it is possible to heat part or the whole of the tank independently with the object of reducing hot-water storage at will during slack hours, reverting to the full storage when baths are required. Hand control by means of a 3-heat switch is usually arranged in this case, the current being left on "low" heat during the night or at slack periods whilst "full" heat on both elements is obtainable when baths are required. Higher loadings are generally used with this arrangement of immersion heating than when automatic control is in use.

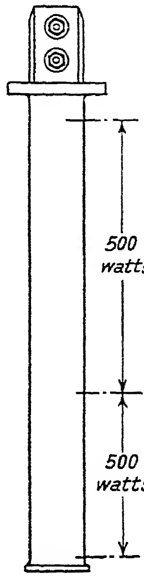


FIG. 50.—Vertical Element with Graded Loading.

Fitting of Elements. The fitting of the immersion heater and thermostat to a hot-water tank can usually be carried

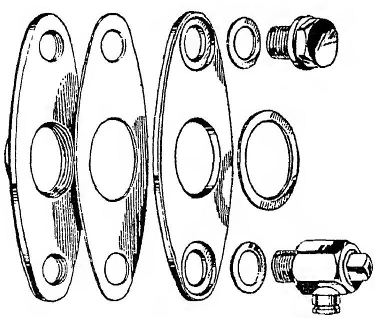


FIG. 51.—Flanged Base Plate.

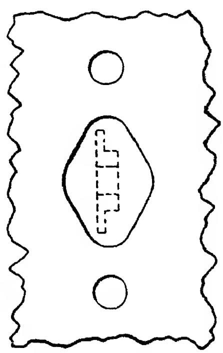
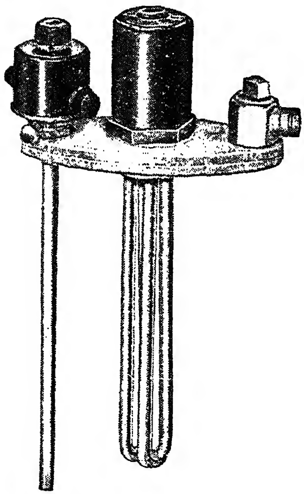


FIG. 52.—Tank cut to pass plate through (dotted position).

out *in situ* without moving or disconnecting the tank. It is not even necessary to remove the manhole cover if one of the special flanges now offered by many manufacturers is used. Fig. 51 shows a typical set and Fig. 53 shows the complete assembled unit. It will be seen from the former illustration that if the tank is cut as shown in Fig. 52 the base flange can be passed inside the tank and the whole bolted up together.



. 53.—Immersion Heater and Thermostat.

There are, however, the following disadvantages to this method of fitting. (1) Thorough inspection of tank is impossible; (2) no baffle can be fitted; (3) when cutting galvanised tanks, the filings fall inside, causing local rust spots to be set up, with rapid deterioration of the tank bottom. On welded tanks or cylinders without manhole covers, the above method is the only one possible, but in all other cases it is highly advisable to remove the cover and make a full inspection of the tank. As a further precaution special tank cutters, such as "Cooke's," can be used so that no filings whatever enter the tank. For cylinders it is essential that curved flanges shall be employed, and these can be obtained in a variety of sizes and types from most manufacturers. Fig. 57 shows a completed tank in position.

For use in soft-water districts, such as Manchester, an external circulator type of element is manufactured. In this case the element is contained in a vertical lagged tube, which is connected by pipe inlets to the top and bottom of the hot-water cylinder. The thermostat is separate,

and is screwed to the side of the bare cylinder, the lagging being cut away at this point. The arrangement has the advantage of giving rapid hot water at the top of the cylinder and no mixing with the cold contents.

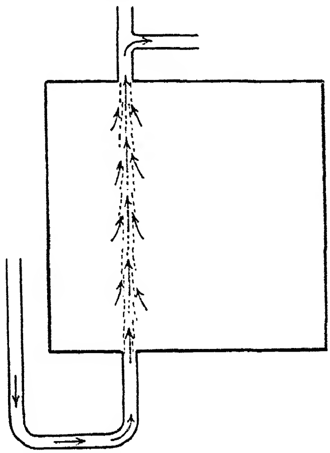


FIG. 54.—Path of Cold Feed without Baffle.

Baffle. Fuel-fired hot-water systems, as normally fitted, frequently contain no device whatever to prevent the incoming cold water from mixing with the hot water at the top of the tank. It is true that the entry is always at the bottom, but if the pipe is vertical and enters through the base the water will bore up through the tank in the manner shown in Fig. 54. When there is a good flow a considerable mixture of cold will then be drawn off even though the tank should still contain ample hot storage. This is in marked contrast to the manufactured heaters when, owing to their cylindricalshape and well-designed baffles, it is generally possible to draw off 90 per cent. of the rated capacity of the container before any considerable temperature drop is noticed (see Fig. 10, p. 48).

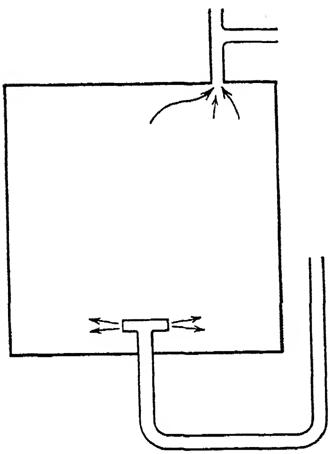


FIG. 55.—Tee-piece Entry.

Such good results as the above are not so easily obtained with a rectangular tank, but a horizontal pipe

entry into the tank side (near the bottom), or the fitting of a tee as shown in Fig. 55, will greatly assist matters. Still greater efficiency will be obtained by fitting some simple form of baffle as illustrated in Fig. 56. The baffle consists of a circular flat sheet, $\frac{1}{8}$ in. gauge, about 6 in. across, which is held in position by two or three $\frac{3}{8}$-in. screwed studs. When fitted to new tanks during manufacture, the galvanizing renders the fixing holes through the tank watertight, otherwise suitable packing washers must be

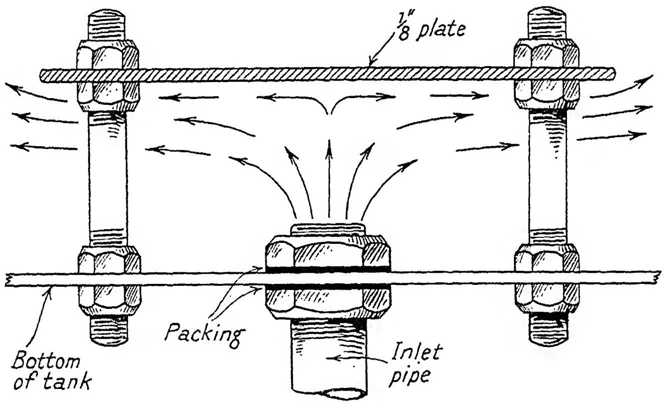


FIG. 56.—Tank Baffle.

used. Alternatively, the supporting posts can be fixed to a strip of iron 6 in. long and drilled centrally to allow it to be fixed under the inlet pipe nut. It is essential that all parts are heavily galvanized.

Lagging. The lagging of the tank is carried out in the very large majority of cases by means of granulated cork in the same manner as with self-contained water heaters. Granulated cork is generally accepted as the cheapest effective form of lagging, especially for use with the rectangular tank common in the south. In other parts of the country, where cylinders are the rule, cork can

again be used, but in this case special fabricated heat-insulating jackets are obtainable. Corrugated cardboard has also been used by one large undertaking, several layers being wrapped round and finished off with a canvas cover sewn on afterwards.

Where a tank or cylinder is situated inside an airing

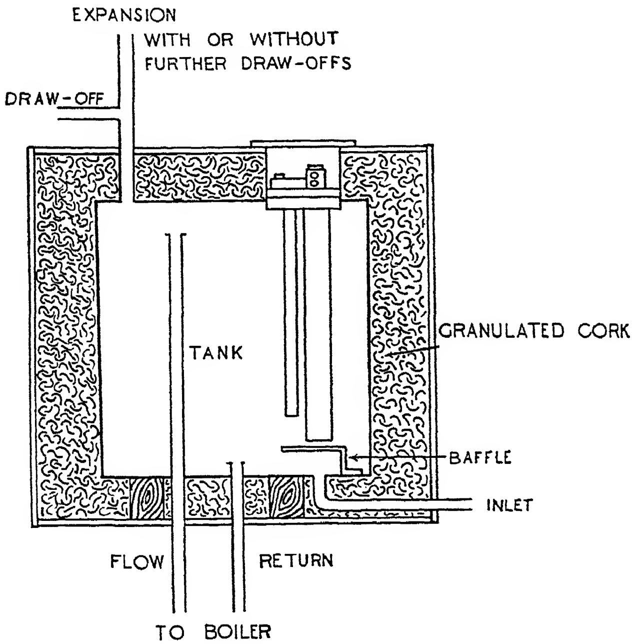


Fig. 57.—Immersion Heater Tank.

cupboard, granulated cork is easily applied by closing the front of the cupboard by means of match-boarding. The cork is then poured in and worked into the space surrounding the tank and finally covered in by more match-boarding over the top. At least 2 in. must be allowed between radiating surfaces and woodwork exposed to the atmosphere. Tanks situated close to brick walls will be to a certain extent heat-insulated by the brickwork, but

care must be taken in this direction, otherwise undesirable radiation losses will be introduced at this point. A typical installation on these lines is shown in Fig. 57. It will be seen that the immersion heater and thermostat are situated on one apparatus plate. Provision for connections and adjustments is made by a stout cardboard collar surrounding the apparatus plate and extended to an external cover on the match-boarding holding the lagging.

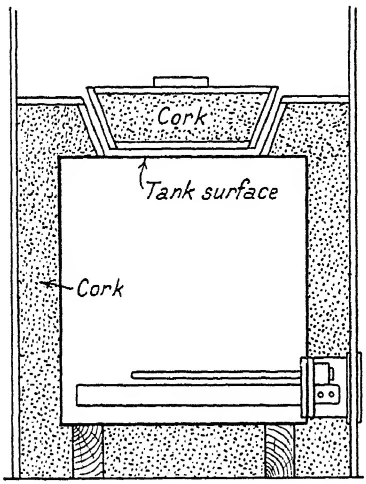


FIG. 58.—Tank Lagging with Removable Lid.

The completely lagged tank has one disadvantage to the consumer who requires a certain amount of heat for airing purposes, and although a small electric heater will make good this deficiency there are some occasions when the escape of heat from the hot-water tank is desirable and necessary. During the winter months, when a solid fuel boiler is in use, it is sometimes found that the boiler raises the water to boiling point, causing noise and, maybe, excessive scale deposit unless some means of getting rid of the excessive heat is found. The tank can be lagged on four sides only with the top left uncovered if desired. This, however, has the disadvantage that when used continuously it is liable to be expensive in use. To control radiation of heat in this way, a detachable lid to the lagging, on the lines of the refrigerator door, is desirable. The consumer can then be instructed to keep the lid in position during the summer except for brief periods of airing, whilst in the winter,

when the waste of B.Th.Us. will not be such an expensive matter, the lid can be left permanently off (see Fig. 58). A cheaper alternative to a joiner-made lid is to reduce the lagging on the top of the tank to 3 in. and to drill the match-board top in several places. This allows for a small heat leakage, which can easily be stopped by covering the holes with a blanket or other material to stop the circulation of air.

The increased efficiency of the whole installation, resulting from the lagged tank, affects the working of the fuel-fired boiler and, as pointed out in the preceding paragraph, boiling sometimes takes place. Attempts to burn the fuel more slowly may be unsuccessful, resulting in the fire going out if the draught is reduced too much. Keeping a low fire, too, may be objectionable, as the need for more frequent attention will arise. The only way to meet this is to give the boiler more work to do. Connections from the flow and return pipes well below the tank can be led to a loop or radiator inside the airing cupboard and will be heated only by the boiler-produced heat (see Fig. 59). As a further suggestion, the installation of a radiator in a convenient passage may be successfully arranged and the heat, formerly wasted in the linen cupboard, transferred to a more useful sphere in some cold corridor.

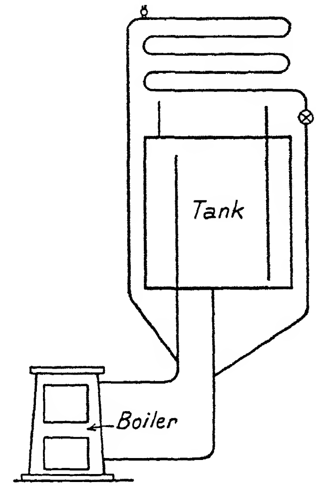


FIG. 59.—Heating Coil operated by Boiler only.

Pipework. As regards pipework, the two main things to look out for are secondary circulations above the tank and hot taps below the tank. As regards the former, the

diagrams in the previous chapter are self explanatory in this respect. Circulations such as those in Figs. 30 and 31 must be cut out, and new direct services must be established for the hot taps. In a similar way the heater shown in Fig. 34 must be shut down when operating with electrical heating in the tank.

Consider next the question of any hot taps fitted below the tank as at D′, Figs. 27 and 28. It was stated in the previous chapter that taps connected to the "flow pipe" obtain the first supplies of heated water, but this is only true when the heat is applied at the boiler. In the present case the heat is applied directly into the tank, and consequently no movement of water will occur in the flow and return pipes. These will be full of cold water at the commencement, and as the only tendency is for cold water to sink as low in the system as possible, no flow will take place. Referring again to Figs. 27 and 28, if immersion heaters are fitted to these systems, no alteration being made to the pipework, when the taps D′ are opened, cold water will be drawn until the boiler, flow and return pipes have been emptied. This will be followed by a mixture of the hottest water drawn from the flow pipe and the coldest water obtained down the return pipe and *viâ* the boiler, which is quite useless.

It will be seen that the tank system presents considerable difficulties to immersion heater operation. It will be necessary either to establish a completely new service to the hot taps or else to abandon this type of conversion and employ one or more self-contained heaters instead. The cylinder system (Fig. 29) will be all right as it stands, but in the case of a system having one draw-off from the flow pipe (D′, Fig. 27), it will be necessary to transfer this pipe so that it is fed from the top of the tank or some part of the draw-off system that comes therefrom. The old tee in the flow pipe must then be plugged off, unless use is found for it as described below.

When the above alteration has been made, it may be found that the installation cannot be drained, as before, for cleaning or repair. The particular tap connected to the flow pipe was formerly used for this purpose, and being

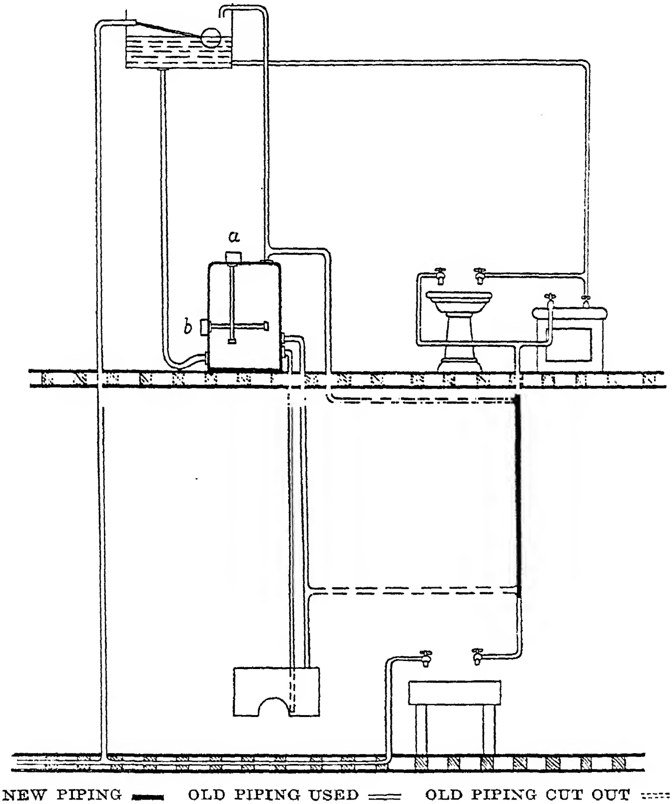


FIG. 60.—Immersion Heater Installation.

plugged off, alternative arrangements must be made before the cistern is refilled. Either a drain cock can be fitted into the tank direct or a sludge cock (with loose key to prevent misuse and a hose union to aid draining) can be fitted into the tee in the flow pipe which is now out of

use. Where a drain cock is already fitted to the boiler itself, this point will not, of course, arise.

Fig. 60 shows the installation of Fig. 27 when converted to immersion heater operation. The hot tank has been fitted with a heating element and thermostat in one or other of the positions *a* and *b*. The sink tap previously fed from the flow pipe has been given a new run, and all other hot taps remain as before.

A final point in connection with pipework is the following. On account of the adverse action of heat upon lead it is advisable to remove and replace with iron any lead pipe that would be likely to be subjected to heat by being in close proximity to the tank.

Indirectly heated (calorifier) systems cannot as a general rule be satisfactorily fitted with immersion heaters, since there are generally considerable lengths of hot-water piping to contend with. A better plan in such cases is to fit one or more electric boilers in series with or independent of the existing domestic supply piping. One such example has already been described (Fig. 44).

CHAPTER VII

ELECTRICITY CONSUMPTION

General. Owing to the uniformly high efficiency of the electric storage heater, the cost of running it will be in almost exact proportion to the amount and temperature rise of the water drawn off. The best way of forecasting the energy consumption is therefore from an estimate of the hot-water requirements. Supply engineers should, however, be chary of giving particular estimates to prospective customers. It is true that all records go to show that the average daily use of hot water does not vary greatly between families of similar size and class ; and such estimates can well be used as a guide to the total load to be expected from a number of consumers. But when put forward to individual prospective users they may strike the occasional exception, and give much dissatisfaction in consequence. A better plan is to give actual figures for the consumptions in similar houses to the one in question.

Energy costs will include the three following :—

(*a*) The actual cost of heating the water.
(*b*) Heater losses.
(*c*) Pipe losses.

The heater losses were considered in detail in Chapter II. and the pipe losses in Chapter III. In the case of displacement heaters or pressure heaters supplying only one or two points close to the heater the pipe losses will be absent or negligible.

In estimating consumptions there are two ways of treating the losses. They can be combined with the useful

consumption, and the whole heater or installation can be treated as operating at a certain efficiency. Alternatively, the losses can be added on separately, whilst the water utilised is regarded as being heated at 100 per cent. efficiency. If the former plan is adopted the overall efficiency (so far as items (*a*) and (*b*) are concerned) can be taken as 80 to 85 per cent. as explained in Chapter II. Item (*c*) will reduce this somewhat if there are appreciable pipe runs.

Taking, as in previous estimates, a mean inlet temperature of 54° F. and a delivery temperature from the top of the tank of 180° F., the output obtainable per kWh. will be 3,415 (B.Th.Us. per kWh.) divided by 126 (temperature rise) and divided by 10 (lbs. per gallon) = 2·7 gallons at 100 per cent. efficiency. A rough figure, including heater and short pipe losses, is that 1 kWh. will give 2 gallons at 190° F. (maximum storage temperature), 3 gallons at 140° F. (sink temperature), and 5 gallons at 105° F. (bath temperature). It follows that a 25-gallon bath at 105° F. will require 5 kWh., or rather less if the heater is fairly well loaded. These figures, it will be noted, are for the annual mean inlet temperature of the water mains, so that more energy will be required in winter and less in summer. As regards baths, the following will show how the amounts are made up, and the first line indicates the storage required at 180° F.

Medium Bath.		Large Bath.	
	Heat Units.[1]		Heat Units.[1]
10 gallons at 180° F. .	1,800	12 gallons at 180° F. .	2,160
Plus 15 ,, 54° F. .	810	Plus 18 ,, 54° F. .	970
	2,610		3,130
Gives 25 ,, $\frac{2,610}{25} = 104°$ F.		Gives 30 ,, $\frac{3,130}{30} = 104°$ F.	
and requires about 4½ kWh.		and requires about 5½ kWh.	

[1] Reckoning from 0° F.

Consumption Analysis. The following analysis is typical of a small fairly compact installation supplying bath, sink and hand-basin and having a 15-gallon tank. The weekly consumptions for a household of three to five are as follows :—

	Equivalent at 180°.	kWh. per week.
50 gallons at 110° for basin . . .	22 galls.	8
60 ,, 140° ,, sink . . .	41 ,,	15½
125 ,, 104° ,, bath . . .	50 ,,	18½
(5 baths at 25 gallons each)		
Tank and pipe losses		14
Total	113 ,,	56

The above will give a yearly consumption of 2,900 kWh., and a load factor of 22 per cent.

A larger household in similar circumstances will consume, roughly, in proportion to their numbers, but there would also be a larger consumption from the same number of persons living in a larger house (with more service points and longer pipe runs) or with more luxurious habits. It will be noted that in the above estimate rather less than half of the consumption is on account of bath water, but in a larger and wealthier house considerably more than half might go in this way.

Whilst local circumstances must always be taken into consideration, a similar rule to the well-known electric cooking slogan, "a unit per person per day," can be used with discretion for water heating. *Two* units per person per day is a good approximation for electric water-heating in the average small or medium-sized house with the normal hot-water requirements.

Three Typical Installations. In order to get a more extended view of probable consumptions and costs, the following table has been prepared, representing three possible installations. Installation A consists of a 1½-

or 3-gallon displacement type heater with a 500-watt loading mounted near and used in conjunction with a sink- or hand-basin. (Hot water may, of course, be drawn off and used elsewhere.) Installation B consists of a 12-gallon heater, probably of the pressure type supplying a bath and one or two other points, and having a 1 kW. loading. This is the minimum installation for bath service, and the consumptions are those for a small house. Installation C is of a 20-gallon heater with a 2 kW. element and intended for a larger house. It will give two small baths in succession or one really luxurious one. The consumptions are less detailed than in the last example, and have been rounded off to show a whole number of kWh. a year. Nevertheless, they are sufficient to give a representative idea of what may be expected. It should be noted that normal losses (assuming a compact installation) have been included, and the water consumptions allow for about three baths a week in case B, and one (somewhat larger) bath a day in case C. In order to complete the picture, typical hire charges and energy costs at two tariff rates are also given.

Installation.	A	B	C
Size of heater (gallons)	$1\frac{1}{2}$–3	12	20
Used for	sink or basin.	bath, sink and basin (small) house).	Ditto, larger house.
Number in household	3–5	3–4	5–6
Weekly water consumption in gallons at 180° F. — Sink, etc.	40	50	70
Weekly water consumption in gallons at 180° F. — Bath	—	30	80
Total	40	80	150
Approximate energy consumption (kWh. per annum)	1,000	2,000	3,750
Quarterly hire charges	4/–	7/–	10/–
,, energy costs, @ $\frac{1}{2}d.$: @ $\frac{3}{4}d.$	10/5 : 15/8	21/– : 31/3	39/– : 58/6
Element rating, kW.	0·5	1	2
Annual load factor	23%	23%	$21\frac{1}{2}$%

Excess Consumption. The question of complaints of cost being excessive ought not to arise if the user understands fully the rigid connection which exists between units and gallons of hot water. Where a special rate is given and water-heating units are separately metered, the actual cost of the service can be arrived at very quickly and compared with previous quarters or a test period. A difficulty which often arises is where two-part tariffs are in force for domestic supply. Under this system one meter generally records the whole of the lighting and water-heating units, together with cooking and heating where either or both of the latter are in use. The bill which arrives at the end of the quarter only gives the consumer's liability in terms of standing charge and units. If the total appears to be high the consumer searches for a reason with a view to economising or possibly finding some fault which is accounting for the excessive amount. The water heater is usually selected as the culprit, since it is one of the few appliances in the house which is trusted to look after itself and with full permission to help itself to current when necessary. "Why, the thing must have been working all day and all night!" it is argued, until it is pointed out that, failing lavish use of hot water, steam must perforce be given off by a heater which continues to use current.

The units consumed by the water heater have therefore to be segregated from the remainder, and there are two or three ways of arriving at this figure. One method is to meter separately for a period of, say, a fortnight the current used by the water heater. With normal use the actual proportions of units per quarter can be calculated and the water heater vindicated. In houses where lighting, heating and water heating are in use, the units used during the summer months are nearly all for water-heating purposes, and the main meter readings covering, say, a fortnight will soon prove what is being used.

Another way which also shows the user the value he obtains for units used, is to arrange for a check test through one complete heating cycle. This can be done by arranging for a reading of the meter to be taken by the householder before retiring for the night, the hot water having being completely used just previously. On the following morning the water heater is switched off and a further reading taken. The user then notes when the hot water ceases or becomes too cool for use, and thus obtains on the one hand the cost of completely heating a certain number of gallons, and on the other hand exactly how long it took for the bulk of that hot water to be used. This test has, incidentally, often proved to what extent extravagant use was being made of hot water in the kitchen. If the water heater is working properly, then the amount of electricity used is in exact proportion to the amount and temperature of hot water used. It is impossible for the heater to use current wastefully if the thermostat is working correctly, and the lagging is efficient and in a dry condition.

As explained in Chapter I., the electrical method is unique amongst water-heating systems in that practically the whole of the energy is necessarily utilised in the process of heating the water, and this fact makes the problem of dealing with complaints an easy one. Once the number of units used by a water heater in a given period has been ascertained, the approximate number of gallons of hot water consumed can be reckoned. If there is any serious discrepancy in the latter figure compared with the user's statements, then the possible sources of waste can be explored.

The reliance placed upon the thermostat to keep the temperature within limits is generally well merited, but if this should fail to cut out at the temperature to which it has been set, boiling will take place, after which all the current used will be wasted. Furthermore, it is

possible that some of the boiling water will be wasted too, as escaping steam displaces it through the expansion pipe. This fault then definitely causes waste of electricity, but it cannot under ordinary circumstances last for long, since the noise and steam emission will soon call attention to it. With self-contained water heaters of the open-outlet type, the steam will appear at the outlet. With cistern or ball-valve types, steam may be seen appearing from the top of the heater or, if this is well protected, from the overflow pipe. Where overflow pipes terminate outside the building, boiling may not always be seen. Where pressure types of water heaters form part of existing hot-water systems, or where immersion heaters are fitted in hot-water tanks, any steam generated will pass through the expansion pipe, and in doing so will usually cause an amount of noise sufficient to be noticed.

One point in the above connection should be mentioned here. Water heaters, particularly in hard-water districts, will often make a "boiling" sound, leading the user to suspect that boiling is taking place. This is the same sound that a furred kettle makes when heating up, the "singing" noise which commences at about 130° F. It need not therefore cause alarm, and the escape of steam is then the only certain sign of boiling—assuming there are no stoppages anywhere.

Some users have on occasion made the complaint that their water heater has been using current all night although only a few pints have been used between 8 p.m. and 8 a.m. Their evidence is that the disc of the electricity meter was turning when they retired for the night after using a small amount of hot water for a wash, and was still turning on first coming down on the following morning. No evidence of boiling can be found, escape of steam, etc., which would certainly have been present had the current remained on all night. The explanation is simply this: the water heater, which was using current

when the householder retired, completed its heating, probably shutting down half an hour later. The gap or differential of the thermostat was such that one of the periods of reheating due to tank losses coincided with the householder's time for rising, and he consequently found the water heater was using current again, though quite innocently, in preparation for his morning bath. The vibration from the opening or closing of a door, or persons descending stairs, would be sufficient to cause a mercury thermostat to close if it was just about to do so automatically.

Erratic working of a thermostat produces very conflicting results and can best be traced by the use of a recording voltmeter or ammeter, which, if left in the heater circuit, will faithfully record the working of the apparatus during a period of several days if necessary.

Leaking taps can be the cause of the consumption rising by several units a day, even in a small house, as the loss of two or three pints of water per hour can easily happen without being realised. Where the users cannot gauge the amount of water that has been used, the test mentioned on a previous page (through one heating cycle) is calculated to enlighten them.

One might be led to the conclusion from the foregoing that the use of a check water meter would be of use in difficult cases, as well as a cleck electricity meter. Though this appears to be feasible, the practical difficulties are considerable. The ordinary type of water meter as used for trade or garden purposes has a comparatively high starting error, which means that any consumption of water at a low rate is liable to escape registration. This is especially so where the water meter is fixed in series with the main water supply to the feed tank. Owing to the slow rate of feed which occurs when the ball-valve is only slightly open, a condition which is accentuated when the ball-valve operates over a large area of water

surface, there is not a sufficient flow to work the meter and actual integration will only take place when a fair amount of water is being drawn. A more accurate way of measuring, if definitely desired, could be effected by noting the drop in water level over a period of time, the ball-valve being shut off between measurements.

The calculation of gallons used is, however, of no use unless the temperature of the hot water supplied remains reasonably stable, and temperatures would have to be taken at intervals to ensure this. Once the user can be convinced that the ratio of hot water to units of electricity is a known quantity, the electrical consumption will provide much the most satisfactory guide, not only to the cost, but also to the quantity and temperature of the water consumed.

CHAPTER VIII

SUPPLY ASPECTS—LOADS, TARIFFS AND COSTS

Potentialities of Load. At the commencement of the book, something was said as to the importance of electric water heating to the consumer. The importance and possibilities of the water-heating load to the supply undertaking will now be dealt with. Thanks to the activities of the Central Board, the supply undertaking has now had its generation problems settled for it. Both the technical and the commercial details are fixed for some years to come, and it can now give its undivided attention to problems of distribution and load building. Backed by the world's finest interconnection system, there is ample capacity for well-nigh unlimited expansion, if only this can be had on profitable terms.

The ultimate limit to the water-heating load is difficult to forecast, but it is certainly very high indeed. There are already some 3½ million domestic consumers, and even if no more were connected, and if only half of them used electric water heating, the resulting load would be about 4,500 million units, whereas the total domestic load at present is only 3,500 million. Moreover, high-tension lines now thread the whole country, and in the course of the next ten or twenty years it is reasonable to suppose that low-tension supplies will be available at fairly cheap rates for practically the whole population. It is therefore no exaggeration to say that the *potential* water-heating load is tremendous, whilst even that which is practically realisable at the moment is many times greater than the business actually being done.

The supply engineer who has not yet started to develop

the water-heating load in his area should consider this branch of domestic electrification in comparison with, say, electric cooking. Good as the cooking load is to the engineer, water heating sells more units per consumer, requiring less capital outlay for the same consumption and with very much lower maximum demand. The heaters themselves will require little servicing, and need very little explanation as to method of use. Every engineer, therefore, who hires or sells electric cookers should hire or sell electric water heaters in addition.

Experience shows that some 2,000 units per annum on an average are used by each water heater. Thus 500 water heaters on circuit, a figure which could be attained in one year in a large number of districts, will add a million units per annum to the load of the undertaking. Water heating is, moreover, the only domestic load of any magnitude that tends (owing to the presence of immersion heater and combined installations) to be bigger in the summer than in the winter.

Finally the possibilities of automatic hot-water supply have already been seen and appreciated by the gas interests, and unless electricity authorities go out for the business here and now, they will realise only too late that the public have been forced to go in for gas on account of the fact that the better alternative was not available.

Actual Results. In quoting the results of one or two outstanding examples of successful water-heating developments, it may be objected that these are exceptional and no guide to general possibilities. The fact is, however, that these undertakings are exceptional only in having tried. Their success is directly traceable to the fact that they have appointed an engineer to give his whole time to specialise on this particular business and have adequately backed and followed up his efforts. Water heating, like many other valuable things, is not one that will sell itself.

There may be excellent apparatus available at reasonable prices and a sound tariff to boot, and yet very little business may be done. Water heating by other means has at the least a hundred years' of use behind it : water heating by electricity is purely a post-war phenomenon, and is still new and unfamiliar. It requires to be *sold*, actively and energetically, before people will buy it.

Such figures are therefore given without apology, and in the full confidence that equal results are obtainable in

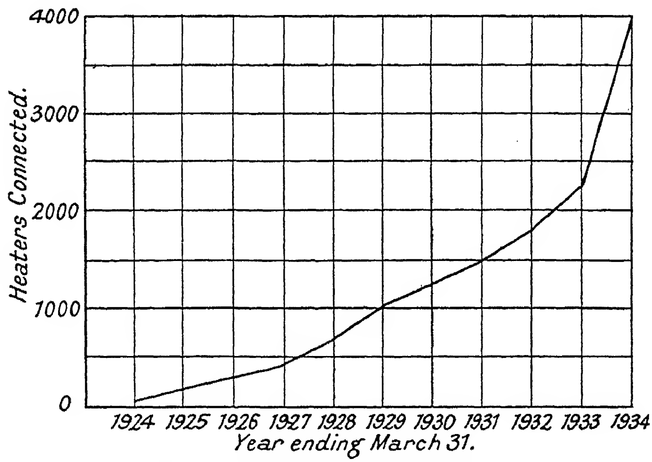


FIG. 61.—Growth of Heater Load.

nine out of ten areas in the country. Fig. 61 shows graphically the net heaters connected to the mains of the Wimbledon Electricity Undertaking in the ten-years period ending March 31st, 1934. It will be seen that an increase of 4,000 was obtained in the ten years, and the growth was at a steadily increasing rate. These figures are supplied by courtesy of the Chief Engineer.

Tariffs. At first, domestic supplies were almost entirely for lighting, and a fairly high flat rate per kWh. was then charged. Such a load is expensive to supply because its

annual load factor is not good whilst its diversity factor is particularly bad, since everyone needs it at about the same time of day. A relatively high price is moreover not only justified but obtainable, since even at this figure a large amount of light is obtained for the money, whilst the quality puts it almost beyond fear of competition.

When domestic consumption for other purposes began to develop it was obvious that the tariff must be both lower and different. A reduction was justified largely because this load was not confined to a few particular hours of the day, *i.e.*, it had a good diversity. And a reduction was necessary before there could be any hope of much heating and cooking business in the face of effective competition from other sources of heat. Not only must it be lower but also a somewhat different kind of tariff was needed from the simple flat rate. A much wider range of uses had to be catered for, and the demand was much more " flexible," and responsive to the tariff presented to it.

Three types of tariff for dealing with general domestic consumption may usefully be distinguished. There are many varieties of each in use in this country, but the one outlined in each case may be regarded as usual or typical. These tariffs all refer to continuous unrestricted supplies. Special tariffs for restricted or alternative services or for special times of day or year are dealt with later in the chapter.

Flat Rate Systems. In this case the lights are supplied from one set of house wiring and the heaters, cookers, etc. from another. Each supply is separately metered and charged for at a separate flat rate per kWh. The lighting rate is commonly about four or more times the other. The chief disadvantage of this system is the two sets of meters and readings which have to be taken, and the double wiring throughout the house. This adds to the cost and also reduces the serviceability, since separate plugs, etc.,

have to be employed. Sometimes special terms are offered for water heating only, and the heater then has its own meter. This may be mounted close to it in order to save wiring costs, though this does not facilitate the meter reading.

Maximum Demand Systems. Both the kW. demand and the kWh. consumption are measured on appropriate types of meter. The charge is either on a definite two-part basis or else the consumption is charged for in two batches. The first batch (whose amount depends on the maximum demand reading) is charged at a high rate and the second batch (*i.e.*, all the remainder) at a much lower rate. This system is very commonly used for power supplies to works, etc., but is much less usual for domestic supplies. Its weakness from the undertaking's point of view is that the maximum demand reading fails to distinguish between different *kinds* of demand; whereas a kW. of demand in the night or morning is immaterial compared with a kW. in the peak period. Its weakness for the consumer is that he never knows quite where he is. If he is contemplating the installation of, say, a water heater, he cannot say (without a very thorough knowledge of its likely uses, cut-in period, etc.) how it will affect his demand reading and therefore what its cost will be. Such apparatus therefore might prove to be quite cheap or quite expensive apart altogether from the amount of its use.

All-in Systems. These are virtually maximum demand systems in which the demand is estimated instead of measured, and in the estimate some account is taken of the probable kind as well as magnitude. The estimate is usually based either on floor space or on rateable value, but there are several other ways. A fixed quarterly charge is then made on this estimate, and all the actual consumption for whatever purpose is metered and charged for at a relatively low running or unit price.

This is now the commonest tariff for general domestic loads and is offered, at least as one of the alternatives, by a large number of undertakings. Once the initial estimate is made the system is easy to meter and account, and is fairly simple to understand. It is very similar to the charge made for a telephone and is familiar matter to the ordinary householder, since it is an exact combination of the usual methods of paying for domestic water and gas respectively. From the point of view of extending the water-heating and other domestic loads it has the very great advantage that the cost of running any particular apparatus is capable of fairly precise prediction. The fixed cost does not normally (and certainly should not) depend on the apparatus connected, so that the cost of using any additional apparatus will be precisely x pence per kWh. where x is the running charge. The value of x is $\frac{3}{4}d.$, or less in a large number of areas, and there seems no reason why it should not lie between $\frac{3}{4}d.$ and $\frac{1}{2}d.$ in any normal urban area. Within this range there is a large field for the development of the water-heating load, profitable alike to the user and the undertaking.

Some critics have argued that such rates are not economically justifiable and that business gained on such terms constitutes a charge on other users. The best answer to this is to point to the number of undertakings with long and varied experience behind them, and who presumably should know their own business best, who are offering such rates. In many cases the normal growth of load has been so accelerated in consequence that prices of supplies for other purposes have been lowered earlier than would otherwise have been possible. Apart from this answer, a costs analysis can be made without difficulty for any given area and will usually confirm the soundness and even conservativeness of figures such as the above. The following rough outline for the country as a whole will be useful as an answer to these criticisms, and also as

a guide to supply engineers in making their own particular analyses.

Supply Costs. Under this heading it is proposed to consider what is the figure at which the supply undertaking should be able to serve the domestic water-heating load, with a reasonable margin of profit for itself. Naturally it is only possible to deal with an average or typical case, and it will be understood that what follows refers to a normal urban residential area without exceptional features in either direction. All the costs are expressed on a two-part basis of so much per annum per kilowatt (or kVA.) of maximum demand plus so much per kilowatt-hour.

Undertakings in this country purchase their energy from the Central Electricity Board, either at the "grid tariff" or at "adjusted station costs," whichever be the lower. The cost of generation may therefore be taken as not more than the grid tariff, which latter is roughly £3 p.a. per kW. plus 0·2*d*. per kWh. There is an increase in the fixed charge for power factors below 0·85, but since the water-heating load can be regarded as being at unity there will actually be a slight credit on this account. Thus an undertaking with a penalised power factor would improve its position by taking on a water-heating load, since it would then pay the Board a slightly lower price per kW. than before. There is also an adjustment of the running charge on account of coal prices, which has been to some extent allowed for in the figure given above.

The next step is to find the cost of transmission and distribution to the average water-heating consumer. This is naturally much more variable than the generation cost, and can only be estimated very approximately. Taking the average for the whole country, the fixed costs of transmission and distribution are about $1\frac{1}{4}$ times the generation fixed costs. On this basis, and allowing nothing for diversity, the fixed charge should be $2\frac{1}{4}$ times

£3, *i.e.*, £6 15*s.* p.a. per kW. of demand coming on to the system. The running charge would be increased only by the amount of the distribution losses, say 15 per cent., making a figure of 0·23*d.* per kWh. The above estimate allows for all essential management and other expenses, but it will be well to add about 10 per cent. for contingencies and profit, and also to increase the fixed charge somewhat to cover the fact that the distribution costs of domestic supplies may be above the average for all supplies. The final cost figure may then be estimated as about £7 p.a. per kW. of system demand plus 0·25*d.* per kWh.

The final and most difficult question to settle is what diversity to allow for the water-heating load, or, in other words, how many 1 kW. heaters can be connected to the mains before the system load at the time of maximum demand is increased by 1 kW. Figures as high as 4 are frequently given by those with good experience in the matter; others prefer a more conservative estimate. The problem is complicated by the fact that the local peak on the distribution network (which largely determines the distribution fixed costs) may not coincide with the peak on the station or the grid. This latter will normally occur between 4 and 6 p.m. on a winter's afternoon; only the four winter months (January, February, November and December) are metered, and the maximum reading (which determines the charge made by the Board) will probably only occur once or twice in the year. Obviously, the likelihood of a thermostatically-controlled heater being on during that particular determining half-hour will not be great—possibly a chance of one in four or five. On the other hand, the local peak in a residential area is made up of other loads of a similar character (heating and cooking), and the chances of any particular heater being on at the peak time are greater—possibly a chance of one in three or thereabouts.

Taking a diversity factor of 3 and a fixed charge of £7 p.a. per kW. of peak demand, this means that the water heater should pay a fixed charge of £2 6*s*. a year for each kilowatt of its loading if it is to pay its fair share of the standing costs. Usually a load factor of 20 to 25 per cent. will be achieved (23 per cent. would mean an annual consumption of 2,000 kWh. on a 1 kW. heater or 3,000 kWh. on a 1·5 kW. heater). The fixed charge would then be equivalent to 0·27*d*. per kWh., and adding the existing running charge of 0·25 this gives an overall charge of 0·52*d*. per kWh. as an economic water-heating tariff.

Any calculation such as the above is necessarily rough and empirical. No two distribution areas are identical, and in particular the question of diversity factor needs far more data than is at present available before it can be more than a shrewd guess. Nevertheless, this is sufficient to suggest that in any normal urban area in this country an unrestricted supply for water heating can be given at an inclusive [1] figure of 0·5*d*. to 0·6*d*. per kWh. without fear of loss and with fair expectation of considerable profit.

Restricted Service Costs. The above costs calculation referred to thermostatically-controlled heaters connected continuously to the mains. There are a number of special types of service which do not come under this heading. These are discussed technically in a later chapter, but it will be convenient to work out their economic supply costs at this point, since it is a simple deduction from what has already been done.

The simplest case is that in which a low-power heating element is permanently in circuit, sometimes with an emergency switch for cutting it out in the event of no water being used. The load factor then is 100 per cent. and there is no diversity. The figure of £7 p.a. per kW.

[1] *i.e.*, without a fixed charge for the water-heating load or any addition to the existing fixed charge.

plus 0·25 per kWh. can then be expressed as an overall charge of either £16 p.a. per kW. of loading or 0·44*d*. per kWh. of consumption (these two will amount to the same thing).

Another simple case is that in which a lower charge is made during the summer months or excluding the four winter months. The generation (or grid tariff) fixed charge is then entirely absent, and the distribution fixed charges can hardly be incurred except in so far as there might be a summer peak in some areas, or the necessity for summer overhauling of plant might be equivalent to this. A reasonable assumption would be to take one-third of the fixed charge calculated for the all-year service, and with the other figures as before this would give an overall charge of $0{\cdot}27/3 + 0{\cdot}25 = 0{\cdot}34d.$ per kWh.

In the case of night load heaters which are switched off during the day or which are connected to a change-over switch as an alternative circuit to lamps or other apparatus, these can usually be treated as a purely off-peak load and entirely acquitted of peak load responsibility. It is not advisable to omit the standing charge entirely, since there are management expenses incurred, and, furthermore, some future change in the system loading might cause the business to become unremunerative. The overall charge may however range anywhere from the figure of $\frac{1}{3}d.$, mentioned above, down to the bottom limit of $\frac{1}{4}d.$ (or thereabouts) imposed by the running charge alone.

Effect of Element Size. In the supply costs calculation just made, the kW. rating (in proportion to the tank size and consumption) has been assumed to be fixed. The actual figure taken was 2,000 kWh. per kW. of loading, giving a load factor of 23 per cent. In practice it probably *will* be fixed, whether at this figure or some other. The makers normally fit a particular size of element to a particular tank, and the recommended

ratings are shown in the frontispiece. Also a given size of tank will, on the average, have a given consumption of water and therefore of kWh. It will be worth while to consider briefly what will be the effect if this ratio of rating to consumption is *not* fixed.

In order to be more specific, consider a 12-gallon tank with a 1 kW. element and consuming 2,000 kWh. per annum, and examine the effect of fitting a 2 kW. element, the tank and consumption remaining unaltered. At first sight this would appear to be an extremely retrograde step. The load factor has been reduced from 23 to $11\frac{1}{2}$ per cent., and the supply engineer who on principle, and almost by instinct, believes in "little and often" will certainly prefer a lower load which is in circuit more frequently or for longer periods. It is ill work for those of us who have never wearied of preaching the supreme importance of load factor now to turn heretic and to attack what is little short of a religious belief. But it is important to distinguish between the individual consumer's load factor and that of the street main or sub-station. In the present case there is reason to believe that the individual load factor is relatively unimportant, and in fact that the diversity factor will go up almost as fast as the individual load factor goes down.

Consider 100 such heaters side by side in a street and assume that the thermostat differential is 15° F. When no water is taken, the heater will switch in about once every eight hours. The only difference between having a 1 kW. and a 2 kW. element is that in the former case the switching-in period would last about thirty minutes and in the latter case fifteen minutes. Since the actual moment of switching-in would depend on the law of chance, there would on the average be almost a perfect diversity between the 100 heaters, and it is doubtful if a meter reading on the street mains would show any appreciable difference between the two cases.

When in use the thermostats would cut in when about $1\frac{1}{2}$ gallons were taken, or less if the tank had been cooling for some time and had come nearer to its natural cutting-in point. The length of time for which the heater would then be in circuit would depend on the amount of water taken, but the time would be half as long with the 2 kW. element as with the 1 kW. If everyone used their heaters at the same time there would be a considerable advantage in the low rating, but with the diversity likely in practice the difference would be very slight. There may even be occasions when the higher rating would be advantageous ; thus with the higher rating, heaters used for mid-day washing-up are less likely to be still in circuit when the late afternoon peak comes on.

Summing up, it may be surmised that whilst it is a sound general principle to install low-rated long-period apparatus, in the particular case of thermal storage heaters it is probable that an increase of, say, 50 per cent. in the loading of a given size of tank would make very little difference to the aggregate demand. From the consumer's point of view there is some gain in a higher loading. Though his normal use will hardly be affected, there may be occasions when he wants to use it heavily or in rapid succession, and a higher loaded element will then be of assistance.

These remarks can hardly be extended to the instantaneous type of water heater. In this case the loading is often as much as five times as great for the same kWh. consumption. Energy is taken only in time with the actual water use, and cannot therefore continue on after the household is in bed. Such a supply is necessarily more expensive to provide, even though the diversity is admittedly enormous.

Effect of Differential. Another point requiring discussion is the differential, *i.e.*, the temperature difference between the cut-in and the cut-out. With the usual type

of mercury tube thermostat it is difficult to make them function satisfactorily with a differential of less than 10° to 15° F. But with the electro-magnetic type the difference can be half as much as this. If the differential is too close the switch will be continually coming in and out and may even chatter. There is also a danger of the water boiling, due to incomplete mixing. On the other hand, if the differential is too great the service is poorer, since the mean temperature is reduced and the temperature fluctuates unduly. Thus a differential of 30° F. on a heater set to 170° F. would mean that if water happened

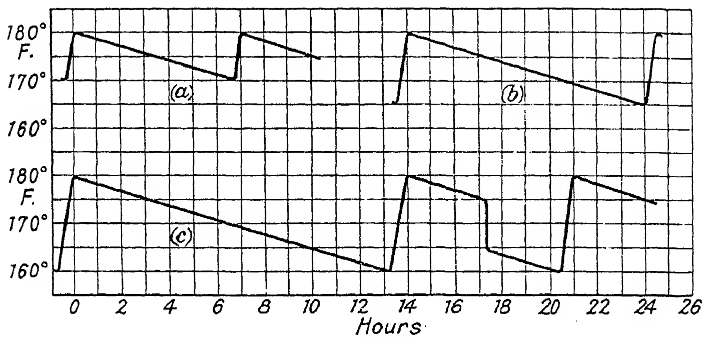


Fig. 62.—Temperature : Time Curves for 20-gallon Heater.

to be drawn off just before the cutting-in point the temperature would be only 140° F. This might be too low for the purposes required or the storage might not quite provide the necessary bath

Fig. 62 shows some hypothetical temperature : time curves for a 20-gallon heater, having a cooling rate of 1·5° F. per hour. Three different differentials are illustrated, namely (*a*) 10° F., (*b*) 15° F., and (*c*) 20° F. In the last case is also shown the result of drawing off a small quantity of water in the middle of the cooling period. Had slightly more water been taken the thermostat would have cut straight in and so altered the sequence

of the curve. Fig. 63 shows an actual test result on a 2-gallon heater for kitchen use. A certain schedule of water consumption was followed, as shown in the bottom of the figure, and this amounted to six complete tankfuls a day. Owing to the small size of the tank the cooling rate is comparatively high (6° per hour), and as the differential is a close one (8° F.) the thermostat is operating more frequently than usual.

An interesting and much debated point concerns the effect of the differential setting on the time incidence of

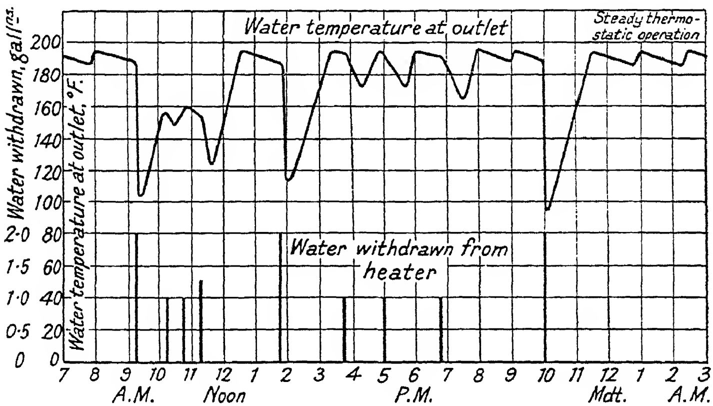


FIG. 63.—Test Results on 2-gallon Heater.

the load. It has been suggested that if the differential is fairly large, drawing off a small quantity of water, *e.g.*, for afternoon tea, will not bring in the heater, and that with any luck it will normally be out, say, from 3 p.m. to 6 p.m. Such a thing would naturally depend on the past history of the particular specimen, but if it were true of, say, 80 per cent. of the heaters on the system it would be an important point in fixing the differential on the one hand, and the tariff on the other.

The general opinion appears to be that a differential of 10° to 15° F. gives a satisfactory working compromise.

The usual cooling rates are from 5° F. down to 1° F. per hour, depending on the size of tank (p. 68). When water is not being used this means that there will be a rest period of three to fifteen hours between thermostat operations with a 15° F. differential. With the normal element loadings the cutting-in periods will then be of fifteen to twenty-five minutes' duration.

There is one final consideration which should be mentioned in connection with both rating and differential, and that is size of leads with its attendant voltage drop. If the house wiring is on the light side, extra cabling may be necessary in order to avoid any effect on the lights when the thermostat cuts in and out. The larger the element and the more frequent the operation, the greater will this trouble become. Some of the more powerful mains-operated wireless receivers announce every such operation with a loud crash, and however appropriate this may be to jazz effects, it is a little disconcerting in the middle of a talk or a classical concert.

Incidence of Load. It was seen above that in making an estimate of the expenses of supplying the water-heating load the crucial question is that of diversity of load incidence, since this determines the magnitude of the fixed costs incurred. Some further discussion of this point may therefore be useful. Taking a general view of the matter, there can be no doubt that the thermostatically-controlled water heater has a load factor which is not only numerically high but which is also of a particularly good character in relation to other loads (power, lighting, and general domestic). This is because the average householder's baths are taken before breakfast or late at night, while domestic cleaning and dish-washing requirements are over by 2.30 p.m., giving the heater time to recuperate and shut down by, say, four o'clock. Add to this the diversity resulting from the slightly different habits of each individual user, and it will be

evident that the effect on the supply network is to build up an extremely useful load requiring very little in the way of distribution expenditure.

At the same time it is evidently impossible to guarantee that the water-heating load shall entirely and invariably

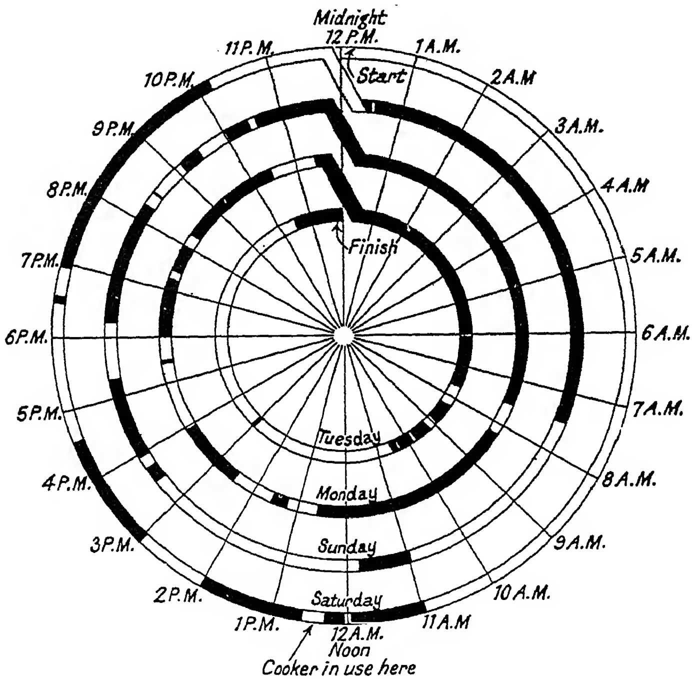


FIG. 64.—Four-day Recording Chart (1·5 kW. immersion heater in 25-gallon tank in private house. Cooker change-over switch installed).

keep clear of the peak. Some small proportion of peak load responsibility must therefore be assumed, and it is unfortunate that precise information on this point is difficult to obtain. In order to get quantitative data it would be necessary to fit recording instruments on, say, 100 installations in a network, at a cost of some £500,

and then to analyse the results over some considerable period. Even then a different area serving another class of house might give very different results. The Americans made a survey in a number of towns in the U.S.A. some years ago, and although of considerable interest the data

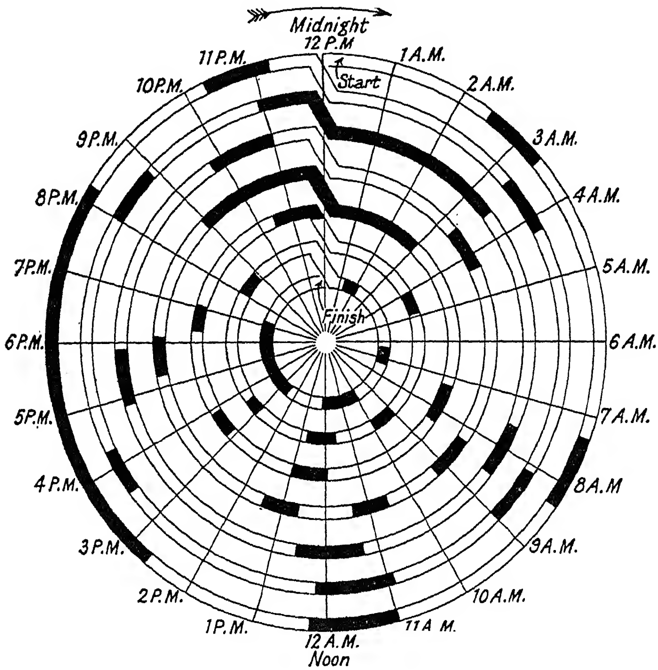


FIG. 65.—Seven-day Recording Chart. (Ten-gallon heater, 750-watts loading, in private house.)

gathered together of consumptions and other points is wholly unusable on account of the different habits and conditions prevailing in that country.[1]

The above remarks have referred specifically to the thermostatically-controlled heater or immersion heater

[1] National Electric Light Association Publication 166, November, 1931.

installation, this being much the commonest type. Hand-controlled water heaters with three-heat control may also give excellent results if the users are educated into the right way of using them. Thus the heat could be left at "low" during the night, boosted to "high" during the morning as required, off from 2 p.m. until 8 p.m. and a final boost for the late evening bath.

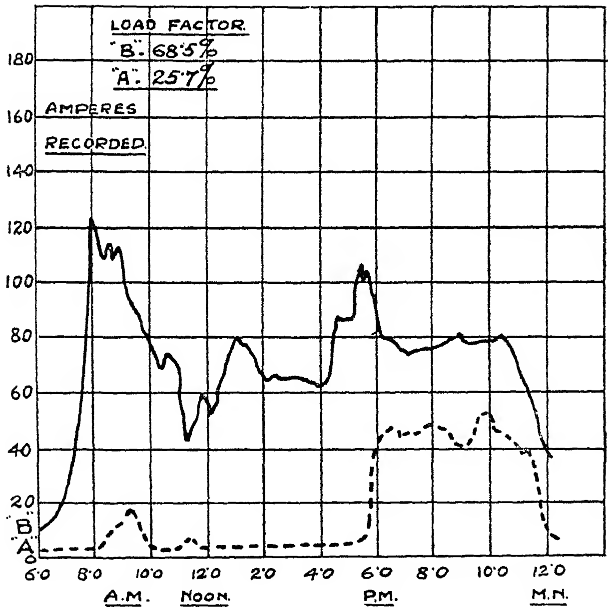


FIG. 66.—Load Curves.

Hand-controlled heaters which are comparatively highly loaded have the possible disadvantage to the supply authority that they may be used only for occasional hot baths. This will mean reduced revenue in proportion to capital outlay and the possibility of coming on to the peak when a child's bath is required at, say, 6 p.m. in the evening.

Some spiral diagrams illustrating water heater load incidence are shown in Figs. 64 and 65. These records, which are taken from recorder charts and translated into a more compact form, faithfully show the habits of a family, say, during week-end, etc. The spreading of the load into the night and its avoidance of the late afternoon peak will also be noted.

The two load curves of Fig. 66 illustrate the magnitude of the load in two residential districts. The full curve shows the effect of heating and cooking in the early hours of the morning. A good proportion of the water heaters would be clear of this peak, waiting until the preparation of breakfast was completed before resuming their work. The dotted curve shows another district of newer houses where domestic electrification is only just commencing.

CHAPTER IX

RESTRICTED SERVICE SCHEMES

THE object of any of these schemes is to keep the load in question from coming on at the peak period, or to limit the amount of load in a house that can come on at any one time. This can be done in a number of ways, of which the principal ones are summarised below.

Alternative Circuits. The apparatus is here connected as an alternative to other and usually more vital electrical services. The switching is done by a change-over switch operated by the householder himself whenever he wishes. Thus a water heater can be wired as an alternative to a cooker, so that both cannot be in circuit together. In a residential area which is well developed electrically and liable to a mid-day cooking peak, such a device will effectually prevent the water heater from augmenting the peak, whilst the storage capacity of the heater will tide it over an hour or two without deprivation to the user.

Another plan is to put the water heater on a circuit alternative to the living-room light, the whole being controlled by a two-way switch. This prevents the water heating load from coming on to the more usual peak period (later winter afternoon), but on the other hand it is a more serious deprivation to the user. A larger capacity tank is required which will withstand six hours' or more disconnection without failing in its service.

Current Limiters. Similar results can be obtained by connecting apparatus in the circuit to limit the maximum load which can be taken. In its simplest form, the load limiter is merely a self-setting overload circuit breaker

which interrupts the supply to the whole house as soon as a predetermined current is reached. The repeated closing and opening of this switch causes the lights to flicker and forces the householder to switch off some non-essential apparatus so as to bring his current down below the critical value. A less barbarous pattern of load limiter is constructed so that its control winding is in series with a lighting circuit. As additional lights are switched in, the current in the control winding rises until it reaches a predetermined figure. At this point an ordinary mercury tube similar to that used in thermostats, and which is in series with the water-heating circuit, is tilted, cutting off the supply to the water heater until the lighting demand is reduced. Thus the lighting circuit always has the prior claim, and there is no cessation of a vital service.

A similar device has been developed for use with a cooker, so that the water heater does not cut out until the cooker load has risen to a critical point. This enables such operations as simmering to be carried out on one or two hotplates for a number of hours without penalising the hot-water supply in consequence. It is, therefore, preferable to a changeover switch, which must interrupt the water-heating circuit regardless of whether the cooker is full on at 6 kW. or only simmering one saucepan at 250 watts low heat.

Time Control. In this system the connection to the water heater is broken for certain definite portions of each day. It was first used (on any considerable scale) for water heaters at Basle during the fuel shortage occasioned by the War (1916–17). The interruption was effected by clockwork time switches, and both these and the heaters were of local manufacture. The system grew rapidly, and in about ten years some 12,000 kW. of water heaters had been installed and the phenomenal load factor of 75 per cent. was achieved.

As the system became less localised, the hand-wound switches were replaced by electrically-wound ones. These require careful initial adjustment, since they are required to go for a longer time without inspection. They have, however, the advantage of being practically unaffected by service interruptions. Several other methods of operating the switches have been tried at different places, the following being the chief :—

Synchronous Clocks. On frequency-controlled A.C. systems, a synchronous clock forms an inexpensive, reliable and exceedingly accurate timekeeper. It can easily be made to operate the switch at the required times of day. Unfortunately, any interruption of the supply causes it to stop, and even if it is self-starting on re-establishment of service, the lost time will cause an error, and all such errors will be cumulative. This can be overcome by having a small electrically-wound movement to look after short interruptions. It will be noted that the time switch must now be connected on the live side of the house switch, so that it is continuously in circuit whatever happens.

Pilot Wire Control. This necessitates an additional "pilot wire" passing into each consumer's premises. Between this wire and one of the mains is a relay which, on suitably energising the wire, can be made to operate the switch. This system has been used in New Zealand for the control of street lighting and domestic heaters. It is only suitable for fairly small, compact areas, owing to the complication involved in the additional mains wiring.

Carrier Current System. An ingenious utilisation of wireless technique has been employed in this connection. A high-frequency ripple can be superimposed on the mains without affecting in any way the ordinary working. At the consumer's premises this can pass through a

condenser (isolating the main voltage), and by setting up resonance in a ready-tuned circuit it can energise a relay and so operate the switch. Arrangement must, of course, be made whereby the high-frequency impulses shall " by pass " the distribution transformers. On the other hand, the ripple can be confined to the required area by the introduction of chokes at suitable points in the distribution network.

In a system recently installed at Idaho, U.S.A., a small 750-frequency alternator can be connected by series-coupling transformers to the feeders leaving the station. By means of a plug-and-jack arrangement, the power station operator can connect to any feeder he chooses, so that the load not only on the station, but on each individual feeder, can be controlled at will. Carrier controllers are used at the water heaters with their contactors arranged to close on a carrier impulse lasting 10 seconds, and to open on one lasting 30 seconds. This timing is automatically carried out by relays actuated by pressing " on " and " off " push-buttons at the power station. A similar device, working at a different carrier frequency, is used to control the street lights.

Choice of System. From the consumer's point of view it is comparatively immaterial what method of switching, etc., is employed—the chief difference for him lies in the length of time for which the service is not available. The supply undertaking, on the other hand, must watch its position very carefully if it is to offer exceptionally cheap rates for off-peak supplies. At present, such a plan is designed to fill up the valleys of the load curve on a low-load factor system ; but when interconnection is complete, and the uses of electricity have extended in directions such as agriculture, railway or road vehicle electrification, and new chemical processes, the load factor may be far higher and the curve quite a different shape. Moreover, if any one class of load is pushed unduly, there is always

the possibility of a peak where now there is a valley—if not on the station, at least on the local distributors. Thus an undertaking which builds up a large night heating load at low prices must beware of its overlapping an early morning cooking or traction peak. It may then be necessary to group the night loads and to stagger the switching times somewhat.

It will be seen that there is much to be said for a switching system that is fairly flexible, and still more for one that is under the immediate control of the undertakings themselves. Obviously, if by carrier current or other means they could in an emergency or for a limited period cut out a few hundred kilowatts of heating load, this would be equivalent to an equal amount of stand-by plant (both generating and distributing) without any of its attendant losses. Conversely, such a method of control would make it possible to give a small daytime boost to a night-load system at any time that the necessary kilowatts were available.

Consumer's Aspect. The objection to any form of restricted service system is simply that its service is restricted. The universal and unfailing availability of electricity for anything and everything is necessarily curtailed if there are to be hours and times. On the other hand, such restriction is probably less irksome with water heaters than with any other form of apparatus. Owing to its storage principle, the effect of a short interruption is slight, and generally the householder will be quite unaware of it. Even a long curtailment will usually mean only that a larger tank will be needed in order to get the same service. The advantage of cheap energy during the night must then be weighed against the extra first cost, rent of time-switch, and (often most serious of all) the difficulty of finding where to put the tank.

Night heating supplies are usually only available from late evening (say 9 or 10 p.m.) to early morning (say

6 or 7 a.m.), a period of 8 to 10 hours. The tank sizes then recommended are 30-, 40- and 60-gallon capacities, with loadings of 2, 3 and 4 kW. respectively. As a result of the necessity for these large storage capacities, night-tariff water heating is often only feasible when it is installed during the erection of the house.

Another of the disadvantages of night-tariff water heating is that on occasion the whole of the storage gets used up either by design or accidental wastage, with the consequential wait until the following morning for a further supply. Such an occasion has been provided for by some supply undertakings, who arrange for a change-over switch at the meter end, so that the consumer can in an emergency obtain a supply during the daytime at ordinary rates. A pilot lamp can be installed, if necessary, to warn him that this is being done.

With some night-tariff rates, in addition to the eight- or nine-hour night period, an extra two hours are included during the midday as a boost. The effect this has upon a pressure type of water heater which is, say, half full of hot and half full of cold water is to " churn up " the contents to one common temperature which, in spite of a two-hour boost, may be too low for particular uses where really hot water is required.

With the ball-valve type of night water heater working on the varying volume principle, the feed is generally arranged to be controlled by a magnetic valve, which is shut whilst the supply is off. The effect of a midday boost in this case can be equally disastrous unless the flow is cut down to equal the heat input for a given temperature rise.

CHAPTER X

APPARATUS SALES AND SERVICE

Sales Policy. Electric water heaters largely come into the same category as cookers so far as sales are concerned. Little progress can be expected if a cash purchase policy only is adhered to. Apparatus of this kind is in the nature of a fixture, and if sold for cash will only be purchased by houseowners of some standing.

To attract the less affluent houseowner, hire purchase must be considered, while the tenant occupier will be attracted by simple hire. Many people make it a principle always to hire apparatus of this sort, on account of the maintenance being covered thereby, whilst many, on the other hand, prefer to own rather than pay rent. A considerable portion of a town's population is constantly on the move, from flat to flat and from house to house, and such, of course, will of necessity only consider hire.

With electric water heaters costing anything from £5 to £20 or more, hire purchase has considerable advantages over a cash purchase policy. The consumer prefers "easy payments," because they get him over the difficulty of laying out capital, particularly for apparatus which he feels may not necessarily do what he requires. With hire purchase, in the majority of cases, he has the power to withhold payment if the performance of the appliance is not up to contract, and this gives him a certain security.

It is advisable that the supply authority should take the initiative in inaugurating a hire or hire purchase scheme. Although an electrical contractor may be com-

petent to advise, install and maintain an electric water heater, it must be admitted that the electricity undertaking has in the very large majority of cases much superior financial resources and the organisation necessary to handle the business and to carry out the necessary servicing. This applies particularly to simple hire schemes, and there is no reason why the contractor should not also do his part in sale and hire purchase, especially if no such scheme exists in his district already. The essential features are that he shall be able to give the right advice and service.

Some undertakings have arranged for their local electrical contractors to carry out the necessary wiring and plumbing work in connection with hired electric water heaters. This might be advantageous to the contractor, since the volume of business would be greater (though possibly the profit per installation may be less), and in addition there would be no responsibility entailed on his part either for advising in the first place or for maintenance after purchase.

When it comes to hire purchase, the contractor can feel that he has more of a share in the business. The supply undertaking, who could, of course, finance the scheme, are in a position to encourage the contractor to introduce purchasers by sharing the discount or paying a commission on such water heater sales. It should be arranged that the supply authority advise on the most suitable apparatus, handling the sale after its introduction, and arranging for maintenance (free or otherwise), whether for a period or indefinitely.

Life and Obsolescence. It is difficult to forecast generally the life of water heaters, owing to the widely varying conditions obtaining. In the past, many undertakings have had to buy their experience at some expense, having invested in apparatus which proved unable to withstand the effects of the local water, or required

constant attention for the purpose of descaling. Originally these heaters may have been expected to last for ten years, but they have been scrapped long before they were worn out because it paid to buy a better design. A good water heater of modern make, however, can be expected to last for ten years at least, the only attention being the periodical clean out, repainting once or twice, and possible thermostat adjustment.

Wear and tear of the material parts of an electric water heater must inevitably bring the useful life of the apparatus to an end. The nature of the water used in the heater will, of course, have a bearing on this point. In some hard-water districts, the constant movement of scale from the element due to its contraction and expansion removes imperceptibly a fine layer of the metal, and this may eventually break down. With soft waters of an acid nature, corrosive action will be the probable cause of the final removal of the heater.

Obsolescence should not be a very difficult problem. The design of pressure water heaters, for example, has not altered materially during the last ten years; that is to say, heaters installed seven or eight years ago need not be scrapped necessarily on being removed from hire, but will be acceptable for hire again after overhaul and re-enamelling. This does not mean, of course, that heaters have not been improved in that period, but, as compared with, say, cookers, they are infinitely more "saleable," as their exterior has not changed to any great extent in shape or finish. Generally speaking, there is considerably less risk of obsolescence with water heaters than there is with most other domestic apparatus, since the design has become very much more standardised.

Maintenance. This term is generally taken to cover maintaining the apparatus in proper working order, and renewing or replacing it when it becomes faulty through "fair wear and tear," *i.e.*, provided the user has operated

it correctly. Moreover, since the heater is designed to be automatic and virtually foolproof, the consumer can usually be absolved from any complicity in the matter. Maintenance is an almost invariable element in hire terms (for the whole period of the hire) and in hire purchase (throughout the purchase period).

Two things may be included in maintenance, namely, a periodical inspection with minor adjustments to thermostats and valves, and a descaling overhaul at much lengthier periods. In practice, the former may often be omitted, and the maintenance resolves itself into attention to complaints and descaling when the occasion demands.

There are, of course, exceptional cases of breakdown which may arise, but these will usually happen during the first twelve months and will normally be covered by the maker's guarantee. Cistern-type water-heaters may call for a little more attention than those of other types owing to the additional complications of the ball-valve. Since this forms part of the water heater, it must therefore be maintained with the rest of the apparatus.

Descaling. The length of time for which a heater can operate without the necessity for descaling depends upon the hardness of the water supply, the amount of water used, and the working temperature. As already explained, a well-designed water heater to a certain extent descales itself and only needs occasional removal of fallen scale and cleaning of waterways. The smaller sizes are generally the worst offenders and may need descaling as often as once every six months. Larger sizes will only need attention after a much longer period, say, from two to three years. Many heaters have been at work even in hard-water districts without attention for over five years, while in London a number of large water heaters in a big block of flats has needed few repairs or cleaning out of any of them for over seven years. Most troubles in hard-water districts are due to stoppages of

outlet pipes, and here again design plays an important part, whilst lower temperature settings will reduce the number of complaints received on this account.

The descaling of a water heater is often found to be necessary after a twelvemonth or so if the thermostat tube tends to collect scale. The action of the scale tends to make the thermostat work sluggishly, increasing the differential and, eventually, causing boiling to take place, and so a vicious circle is formed.

In soft-water districts, overhauls are reduced to a minimum, and provided that the water has no deleterious action on the metal with which it comes in contact, there is nothing to prevent a water heater working for five to seven years without descaling and with only minor attention or adjustment.

The operation of descaling is simple and inexpensive. The apparatus plate is dismantled and the scale removed with a chipping hammer and chisel, while the top of the interior of the container can be cleaned with a long chisel or similarly constructed special tool. Before commencing to descale it is essential that the entire contents of hot water are first drawn off and the water allowed to continue to run cold for several minutes before the valve, fitted in the inlet, is closed and the draining plug of the heater removed. If this precaution is not taken the residual heat retained in the lagging will be so great that it will be almost impossible to put one's arm within the container to ascertain its condition or to assist in descaling.

The main formation of scale is usually at the top ends of the elements and thermostat casings and the outlet pipe, which is often found nearly choked up or very restricted in bore. In fact, it is usually the complaint of poor water flow that gives the first intimation of cleaning being required.

The incrustation at the top of the heater is not so

harmful, as, being a poor conductor, it does not tend to inefficiency, and the loss of volume is quite a small consideration, but it is essential that it should be thoroughly cleaned around the top outlet to assure that the maximum clearance will be available when completed.

The entire work usually takes two to five hours, and for the larger sizes of water heater of 12 gallons and over costs not more than 10*s*.

Economic Hire Charge. If the hire charge is to be economically correct, *i.e.*, if it is to cover all the actual bare costs incurred, it must include three things: (*a*) interest on capital, (*b*) provision for replacement, and (*c*) provision for maintenance. Assuming interest at 5 per cent. throughout, the cost of (*a*) is 5 per cent. per annum on the capital cost of the heater plus any wiring, etc., included. The cost of (*b*) is that sum which, deposited at suitable intervals in a sinking fund, would amount to the first (or replacement) cost at the end of ten years (only the heater price, not wiring, can strictly be covered by this). This sum is 7·8 per cent. per annum on the first cost, assuming quarterly deposits in the sinking fund and compounding at 5 per cent. The total for (*a*) and (*b*) will then be 12·8 per cent. of the capital cost of the heater, neglecting any payment for wiring. The figure is not directly proportional to the rate of interest owing to the sinking fund accumulations. Thus if interest were at 4 per cent. throughout, the total would be 12·2 per cent. of the capital cost; with interest at 3 per cent. the total would be 11·6 per cent.

Against the above must be put any credit due to the scrap value of the heaters at the end of the ten years. If, for example, it were found possible to recondition them at a cost of half the original purchase price, then the correct total cost (with interest at 5 per cent.) would be $5 + 7{\cdot}8/2 = 8{\cdot}9$ per cent. per annum of the first cost.

As regards maintenance, it has been suggested that a

figure of 9*d.* a quarter (*i.e.*, 3*s.* a year) will cover any inspection or minor adjustment necessary, and with heaters giving no trouble on this score it would approximately cover descaling every few years.

Summing up the position, it may be said that an annual figure of 3*s.* plus 10 per cent. of the first cost should cover the bare costs under average or rather favourable conditions. This allows nothing for overhead or management expenses but it should just keep the hiring work solvent without, on the one hand, making a profit, or on the other hand, taking credit for the revenue to be earned. Undertakings which wish to develop their water-heating business will be well advised not to charge much more than the scale suggested above. (The figures in the frontispiece are based on this scale.) As to how far below these figures it is advisable to go must be purely a question of policy. It then becomes a slight subsidy to the hiring department on account of potential revenue-earning capacity.

Typical Hire Figures. Turning now to the hire charges actually employed, it will be appreciated that these (like the charges made for the electricity itself) are often a question of policy as much as of economics. Moreover, the undertaking has probably already some previous experience upon which it can act, since there are very few now who do not hire in some way some sort of electrical apparatus. The following figures give an indication of the general trend of hire charges :

	A	B	C
1½ gallon	2/–	4/–	1/6
5 ,, ...	3/6	5/6	3/–
12 ,, ...	5/6	8/–	4/–
15 ,, ...	6/–	10/–	6/–
20 ,, ...	7/–	12/6	8/–
Immersion heater (hand-controlled)	—	—	2/6
Immersion heater (with thermostat)	4/–	6/–	4/–

Case A. The figures given by this undertaking (municipal) refer to hire charges for electric water heaters only, and no fixing is included, with the exception of the immersion heater, which figure includes fixing to an existing tank, lagging and wiring up to 30 ft.

Case B. A typical case where rentals include in every case wiring up to 30 ft. (company undertaking).

Case C. This undertaking has built up a large business with the very reasonable rentals shown, each of which include wiring up to any length.

Hire Purchase. In place of a simple hire scheme in which the heater remains the property of the undertaking, a hire purchase arrangement is sometimes preferred. The period chosen is three to five years, at the end of which the undertaking ceases to make any charge for the apparatus, abandons its ownership, and gives no further free maintenance. The property of the apparatus then becomes vested in the consumer or his landlord. The former is free of course to determine the hiring at the end of a shorter period if he desires, as when changes of tenancy take place or if he is no longer able to afford to run the apparatus. But he is encouraged to look upon the transaction as an eventual purchase and so feel that he has some stake in the apparatus.

The charge made must, of course, be greater than that required for simple hire. A reasonable allowance will be to spread the purchase price over the total number of payments and charge 5 per cent. on the outstanding amounts. For a five-year period, this will mean paying each quarter about 5·7 per cent. of the heater purchase price, to which must be added the 9*d*. for maintenance.

Other Costs. It is sometimes advisable to include a certain amount of the fixing (*i.e.*, wiring and plumbing) charges in the rental charges for water heaters or immersion heaters. When this cost can be averaged out at a

suitable figure for inclusion in such rental, it must be viewed from the standpoint that the fixing material and labour cost involved are irrecoverable and cannot be treated in the same way as the heater itself. These costs must be covered by making the period of hire sufficiently long so that they are repaid by the additional rental charged in this period, *e.g.* :—

> Heater rental per quarter 5*s*., cost of fixing £2 8*s*.
>
> Heater rental, including fixing, per quarter, 5*s*. + 4*s*. = 9*s*., with three years' minimum term of hire.

In this way, 4*s*. per quarter represents a hire *purchase* (for a three-year period) of the fixing costs. Similarly with immersion heaters, the hire charges should have covered the labour costs and irrecoverable items by the expiration of the term of hire.

Other recurring costs can generally be neglected, *e.g.*, those for the incidental expenses in accounting and rendering the hire charge. Where a special rate is given for water heating involving the use of a special meter, the hire charge for this and the cost of meter reading will have to be included in the water heater hire charge. The cost of this item, however, can be recovered through the unit charge.

With " off-peak " and other restricted systems, the use of a time switch or other interrupting device becomes necessary. The hire charge for this (together with a separate meter) is best rendered as a definite extra, and not included in the unit charge. The cost to an undertaking of a synchronous time switch and meter is in the neighbourhood of £6 to £7, so that a hire charge of 5*s*. per quarter for these items will cover the capital cost in a reasonable time. Here, again, the maintenance of this gear should be negligible.

One final point worthy of mention is of the recently obtained concession from the Inland Revenue Authorities,

who have agreed to an allowance for depreciation in apparatus hired by electricity undertakings as an abatement in Income Tax.

Choice of Heater. Where heaters are to be hired, and consequently only certain sizes of specified makes are to be available, it is essential that the heater selected shall be as adaptable as possible, both from the point of view of installation and use. Taking the supply side first, heaters are obtainable that convert, by only changing the fittings of the respective outlets, to fulfil either the open outlet (displacement type), semi-pressure for supplying direct to one point only, or semi-pressure serving several points. Adaptability such as this constitutes an assurance that there will not be at some future date large numbers of one particular type lying idle, when the demand happens to be for immediate delivery of some other type which is not in stock.

From the installation engineer's point of view, some heaters are particularly adaptable to meet varying conditions. For instance, in displacement-type heaters, taps that are reversible for either left or right of the heater; whilst swivel spouts as standard fitments ensure that the heater can be fitted to one side of a bath or sink, while the discharge can be directed to any given point as required. The disposition of the pipe connections can also be of great assistance, or otherwise, towards making the fitted heater a neat and unobtrusive job rather than an unsightly mass of tangled pipes and ungainly bulk.

OUTLINE OF GENERAL SALES SCHEME

Taking local conditions into account, it should not be difficult to evolve a sales scheme for the hire or hire purchase of electric water heaters and to decide on the best policy for carrying out the business. The first question, no doubt, will refer to the number of sizes to be

offered. Then will come the rentals, which may or may not include the fixing. This point raises the question of employment of the supply authorities' own workmen for both wiring and plumbing, or whether this should be in whole, or in part, carried out by private enterprise. Alternatively, the wiring and plumbing, if done at the consumer's expense, could be paid by instalments spread over a period. It must be remembered, however, that in case of default there is nothing recoverable of much value with the exception, of course, of the heater itself. If the available tariff for water heating is over $\frac{3}{4}d.$, it would be advisable to commence with the $1\frac{1}{2}$-gallon size only, until the public had some idea of the advantages of the electrical method. Larger heaters would possibly run up big accounts with consequent dissatisfaction and bad advertisement. With current available at $\frac{1}{2}d.$ per unit, a much more ambitious scheme can be attempted.

Showroom Display. In the supply authority's showroom should be a model bathroom fitted with bath and lavatory basin and connected up with running water. An open outlet heater fitted over the bath can then be demonstrated under working conditions, while the taps can be connected to an immersion heater installation or ball-valve water heater, fitted elsewhere. This can also supply an adjoining kitchen sink, if required, thus showing the service electric water heating gives. A small water heater can be fitted over the sink as well, thus completing the representative display. An immersion heater and tank in section, with tank cut away, is a good way of demonstrating this apparatus, and if it is made movable, it can be used for window displays.

Staff. A male member of the sales staff with a practical outlook should undertake the commercial development of the water-heating load. At the same time, his technical knowledge should be sufficient to discuss electrical and

hot-water details with architects and consultants. In addition to this man, each member of the sales staff should have instructions in the primary business of interesting consumers in the subject.

The installation and maintenance side will usually come under the ægis of the department entrusted with the care of hired apparatus, with a plumber-mechanician responsible to the departmental superintendent for the fixing, installation and upkeep of apparatus, also for the estimating and for the advising of the sales department. All maintenance men should be able to effect simple adjustments and repairs to water heaters as part of their usual routine work.

Advertising. It is advisable to launch the scheme with good advertising, commencing with space taken in the local press, and synchronising with an effective window display at the showrooms. Circularising picked roads or districts, or amongst cooker users, where special terms are given for the combined services will be an advantage. A pamphlet explaining the system of water-heating with prices, rentals and other particulars is essential; or alternatively, a series of small pamphlets or leaflets, one being a short explanation and summary of electric hot water, such as issued by the E.D.A., with additional "slip-in" leaflets illustrating the heaters. These can be altered from time to time or enlarged as required. Co-operation with local building firms is advantageous, especially if special discounts on sales are given as an encouragement. In new houses it is often possible to arrange for the hot-water tanks to be flanged ready for the easy installation of immersion heaters, or if this is not possible, a small "stick-on" label on each tank will remind the user of this possibility.

Exhibitions. Show houses or flats are often good opportunities to introduce apparatus, and should, if at all

possible, be on circuit and ready for demonstration. The current cost is reasonable, and is often borne by the builder. Local exhibitions held in halls, etc., give an opportunity of educating the public, and would call for similar treatment as a showroom display. Continuous running hot water from a heater into a bath is an attraction, and needs a pump made to stand up to hot water and a special loading of 5–6 kW. to keep the circulating water heated. Soft water should be used, however, as the bath soon gets discoloured with the lime deposit.

Education. In order to implant the electric hot water idea into the future consumers of electricity, it is a good plan to get water heaters installed in as many schools as possible. These can be installed in homecraft and laundry centres and actually used by the children, while a heater in the medical inspection room is seen regularly by nearly every child in the school. Pictures and data on this subject in the possession of teachers for occasional object-lessons is only in line with present-day practice, and is to be encouraged.

Maintenance and Service. One need not emphasise the importance of service for the user of electric hot water, and it is just as important that an electric water heater should be serviced promptly as a cooker, kettle or other domestic appliance. The faults occurring on a water heater are mostly negative, and, being so, do not acquaint the user of possible trouble until the hot water fails either in heat or in flow, leaving him without the service he has grown to appreciate and depend upon. He has no alternative that he can call into use quickly, as with a cooker where other parts of the stove will carry on the cooking in case of a fault. Thus it is in the supply authority's interest to get the water heater on circuit again as quickly as possible, and to restore the service of hot water to its former efficiency.

The maintenance engineer will be called upon to deal with faults both electrical and hydraulic, and these are summarised in the paragraphs below.

Electrical Faults. Failure of the water to heat may arise through several causes. Faulty working of the thermostat is a common cause and is due to the action sticking, thus keeping the mercury tube from tilting (or contacts closing) and making the circuit. Element failure is not a common occurrence, but this may arise due to a burn-out (excessive scale may be the cause), or by burning off at the terminals, which can be cured in most cases by doubling the element at the terminals. External interruptions are, of course, excepted.

Boiling of the water, or unusually high temperature, may also result through the thermostat action sticking and keeping the circuit closed after it should have been opened. A cracked mercury tube may cause this, as the air getting into the tube will oxidise the mercury by the heat of the arc made every time the circuit is broken, leaving a deposit on the bottom of the tube. The mercury is liable to be held up by the deposit, and a small conductive path is left, although the tube is tilted above horizontal.

Intermittent boiling may also take place in a water heater run at temperatures of 190° F. or thereabouts, where the thermostat tube has become heavily scaled, and therefore sluggish in action.

Boiling may also bring other troubles in its train, apart from complaints on the score of consumption. The collection of steam due to boiling at the top of the water heater should not take place to any extent, as the open outlet or expansion pipe should allow a free passage for its relief. Where an expansion pipe has become choked with scale, the pressure of steam at the top of the heater with rise until it overcomes the weight of the water in the cold feed cistern. The contents of the water heater

will then be forced up into this cistern *viâ* the cold feed pipe. Sometimes this may happen with such speed that the overflow pipe has not time to carry away the excess water, which consequently rises and spills over the open top of the cistern. This same trouble will occur if boiling takes place in an installation where the expansion pipe has in error been taken from the bottom outlet of the heater, instead of from the top.

Irregular working of a thermostat can best be detected by a recording ammeter or voltmeter connected in circuit with the element, so that it shows exactly when the thermostat cuts in and out over a period of days. Occasionally, voltage fluctuations are the cause of unsatisfactory operation, and if these are suspected a recording wattmeter or voltmeter should be employed.

Hydraulic Faults. Failure of water to flow is generally an external fault, save where it can be reasonably assumed that the heater has become choked due to scale, or in any other way. Ball-valve or cistern types of water heaters, however, may develop internal faults, preventing the flow of water. The ball-valve itself is generally the offender. Owing to the limited space in which it has to work, the valve does not get much play between open and shut positions. Consequently it may remain on its seating due to the wearing of the rubber washer in such a way that it tends to form into a stopper, rather than a flat washer, and so remains closed. Poor cold-water supply pressure accentuates this fault. In some types of restricted flow heaters, the orifice through which water flows into the storage cylinder from the cistern becomes choked. This fault, however, has been rectified in most of the latest heaters of this type.

Another ball-valve trouble is that of failure to close. This again is inherently due to the confined space in which the ball-valve works. Owing to the comparatively short length of ball-valve arm and less leverage in consequence,

difficulty may be experienced in getting the valve to remain closed. This fault is accentuated by excessively high pressures of cold-water main supply. A larger ball often gets over this difficulty.

Some water supplies have a chemical action on the soldered seams of valve balls, which soon leak and get waterlogged. The valve ball should therefore not be submerged with its soldered seams below water level. Solder causes trouble in another way (generally in new installations), when small pieces of the metal are washed into the ball-valve seating, causing a slight leak.

The excessive dripping of water heaters with open outlets is a complaint that is often received, and is sometimes difficult to cure. Strictly speaking, the anti-drip device is fitted to prevent dripping, but experience shows that the majority of complaints are on account of the excessive amount of water which runs from the heater after the tap has been turned off. This is, in the majority of cases, inevitable, and is simply due to the siphon working in the normal way. It may take some half minute or so to finish, but should then be perfectly still. If a steady drip commences some time afterwards, it would indicate that the control valve leaks and needs rewashering. This initial overflow cannot, of course, be altered except by a change in design, and it would seem that further progress must be made before perfection is achieved in this respect. There is no reason, however, why this water should be wasted once the user has acquired the habit of turning off shortly before the desired quantity has flowed.

Hot Water by Contract. Over twenty years ago the electrical industry had the credit of introducing to the public for the first time a hot-water system with a contract price per quarter covering everything—supplying and fixing the heater, maintenance and energy. The late Mr. C. Orme Bastian was responsible for the introduction

of this innovation, and his well-known Bastian water heater was the apparatus used. This heater, which consisted of a simple tinned-copper cylindrical container, lagged with wooden slats, was fitted with a ball-valve inside and covered by means of a close-fitting double lid filled with asbestos. The heater worked on the principle of constant temperature and varying volume, and the water was adjusted to flow into the heater at such a rate that the heat applied would raise it to a temperature of approximately 160° F. The element was of the flat mica type, clamped to the underside of the copper bottom after the fashion of some makes of electric kettle.

The heater was arranged to be run off the lighting circuit, and its units metered together with lighting units. As the current was on continuously, the consumption per quarter was simply the product of the loading, the number of hours per day, and days per quarter. This number of units would be deducted from the total reading, giving the amount used for lighting purposes to be charged at lighting rates and leaving the water-heating units at their special price based on the 100 per cent. load factor obtained.

Thus the current consumption and charges were always the same, and together with hire and installation charges, formed the contract price for the hot-water service.

No thermostat was fitted, as it was argued that if the water was not used it gradually rose in temperature, giving the consumer the benefit by having hotter water available. The water, however, never boiled, as radiation losses equalled heat input by the time the temperature reached 180° F. approximately. These same principles are in use to-day, with modifications, on the later type of heater.

Similar contract systems have been tried with thermostatically-controlled water heaters, in which case the

supply authority may stand to lose if the charges are based on an estimated average use of hot water per day, and the consumer is consistently extravagant. On the other hand, economy of hot water does not reduce the cost to the user who, while ready to get something for nothing, is ever on his guard against paying for something he does not get. This probably explains the reason why this system has not gained much ground, either with electric or with gas-heated thermal storage heaters.

USEFUL DATA AND ASSUMPTIONS

[These are employed throughout the present book unless otherwise stated.]

British Thermal Unit (B.Th.U.) = heat required to raise 1 lb. of water 1° F. = 252 calories = 1,054 joules (watt-seconds) = 0·293 watt-hours.

Hence 1 watt $= \frac{1}{\cdot 293} = 3{\cdot}415$ B.Th.Us. per hour.

1 kilowatt-hour (kWh.) = 3,415 B.Th.Us.
1 therm = 100,000 B.Th.Us.

Inlet temperature to heater (mean of Metropolitan Water Board's mains)	54° F.
Outlet temperature from top of heater . . .	180° F.
Temperature rise imparted . . .	126° F.

Energy required per gallon to do this
= 0·37 kWh. at 100% efficiency.
= 0·46 ,, ,, 80% ,,

Approximate heat losses per sq. ft. of rough dull surface per 1° F. temperature difference—

from tank or vertical pipe	0·63 watts or	2·2 B.Th.Us.	per hour.
from horizontal pipe, $\frac{3}{4}''$ bore	0·73 ,,	2·5 ,,	,,

Heat losses from complete heater with thermostat set at 180° F., 4 watts per sq. ft. of external surface.

Average price of electricity for water heating is taken as mean between $\frac{1}{2}d.$ and $\frac{3}{4}d.$, *i.e.*, $\frac{5}{8}d.$ per kWh.

Size of tank in gallons: length × width × depth (in feet) × $6\frac{1}{4}$.

Water expands 8 to 10 per cent. in freezing, and approximately 4 per cent. from cold to boiling.

Capacity of pipes. Length required to contain one quart:

$\frac{1}{2}$ in. . . .	31·25 ft.
$\frac{3}{4}$,, . . .	13·12 ,,
1 ,, . . .	7·35 ,,

INDEX

FLEXIBACK BINDING
Patents Pending